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# STUDIES ON THE ENVIRONMENT AND EUTROPHICATION OF LAKE MICHIGAN

John C. Ayers, et al

Michigan University
Ann Arbor, Michigan

1967

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THE UNIVERSITY OF MICHIGAN

# Studies On The Environment and Eutrophication of Lake Michigan

JOHN C. AYERS
DAVID C. CHANDLER

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**Special Report No. 30
of the
Great Lakes Research Division
Institute of Science and Technology**

422

# STUDIES ON THE ENVIRONMENT AND EUTROPHICATION OF LAKE MICHIGAN

John C. Ayers and David C. Chandler

Final Report of
U.S. Public Health Service Grant WP-00311

Details of illustrations in this
document may be better studied
on microfiche.

Special Report No. 30
Great Lakes Research Division
The University of Michigan
Ann Arbor, Michigan

1967

I

# PREFACE

Project WP-00311, entitled "A Coherent-Area Study of Lake Michigan," involved a multidisciplinary team approach to the biological, chemical, and sedimentary indications of the eutrophication process in the southern two-thirds of Lake Michigan. It also involved studies of weather- and air mass-modification by the lake and studies of the physical circulation of the lake as pertinent ancillary matters capable of influencing the expressions of eutrophication by lake parameters. Included also, as fundamental background, were studies of the bedrock framework of the lake basin and such additional facets of the geological history of the lake as were possible.

This has been called a "Coherent Area" of researches because of the limited geographical area involved, and because of the interrelated interdisciplinary nature of the studies. Furthermore, the term implies our firm and growing conviction that piecemeal or partial attacks on the complexes of problems cannot produce the body of integrated knowledge needed for the understanding and eventual management of the Great Lakes water resource.

Although this four-year study has not supplied definitive answers to many of the Great Lakes problems, it has however produced a significant body of new knowledge on the nature and behavior of a large lake, especially the rates and processes now operating in lower Lake Michigan. It has established a base line or reference point for the determination of rates and nature of changes in the quality and quantity of benthos, phytoplankton, and zooplankton; the concentration of certain nutrients; temperature cycle; level of oxygen concentrations; erosion and deposition; patterns of water circulation; and the climatic and meteorological conditions.

Knowledge acquired from the "Coherent-Area Study" makes it possible to attack in a meaningful way for the first time certain specific Great Lakes problems such as:

1. Mechanisms of eutrophication
2. Nutrient budgets and cycling
3. Energy budgets and trophic dynamics
4. Environmental requirements of biotic species
5. Long-term monitoring of significant environmental factors
6. Mechanisms by which pollutants affect species of biota
7. Mechanisms of sedimentation and erosion

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8. Use of microfossils and chemical content of sediments for constructing the environmental history of the lakes

9. Use of remote sensing techniques from planes and satellites for measuring the lake environment and atmospheric conditions

10. Use of research submarines for observing and sampling the lake environment at great depths

11. The impact of land drainage on lake processes

12. Exchange of chemical substances between atmosphere and lake surface

13. The impact of socio-economic factors within the drainage basin on lake characteristics, and conversely

In order that the final report be written before the termination of the four-year grant, the results presented here are, for the most part, the results of three years of laboratory and field work. Field and laboratory studies were continued in the fourth year, although at a reduced level, and the results when analyzed will be published in scientific journals. Furthermore, much of the data presented in this final report will be reworked and will furnish the basis of a series of papers to be published in scientific journals.

We wish to emphasize that this "Coherent-Area Study" has permitted us to study Lake Michigan through an integrated approach, a situation impossible through individual project grants alone. Benefits derived from this approach are far beyond the data presented in this final report. All who have participated in this study have come to view the Great Lakes as an integrated system, and individual projects have meaning only in reference to the entire system. This has developed a viewpoint we consider essential for an effective attack and ultimate solution of Great Lakes problems. Furthermore, the individual projects conducted by the Great Lakes Research Division staff, which were supported independently of the "Coherent-Area Study," benefited tremendously from the background information derived from the "Coherent-Area Study." Individual projects became in clearer focus because of the larger integrated study and have produced results of greater meaning. These benefits, along with the viewpoint that the Great Lakes represent an integrated system, will in the future greatly influence Great Lakes studies.

The project has produced 22 unpublished meeting-papers given at scientific meetings, and 14 seminars given at educational institutions. The scientific meetings included: American Society of Limnology and Oceanography, Great Lakes Conference, Midwest Benthological Society, Ohio Academy of Science, Michigan Academy of Science, and American Society of Military Engineers. Seminars were given at: The University of Michigan (including Office of Naval Research Seminar in Meteorology and Oceanography), University of Vermont, Adelphi University, University of Illinois, Grand Valley College (Michigan), New York University at Fredonia, and Duke University.

We wish to gratefully acknowledge the following senior staff members who have carried responsible supervisory duties in the conduct of this study:

| | |
|---|---|
| Frank R. Bellaire | Meteorology |
| Floyd C. Elder | Meteorology |
| Jack L. Hough | Geology |
| Vincent E. Noble | Physics |
| Charles F. Powers | Limnology and Benthic Organisms |
| Andrew Robertson | Limnology and Zooplanktology |
| Eugene F. Stoermer | Limnology and Algology |

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David C. Chandler

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# COMPARISON OF THE DISTRIBUTION OF ORGANIC MATTER IN THE FIVE GREAT LAKES[1]

Andrew Robertson and Charles F. Powers

Abstract. The five St. Lawrence Great Lakes are compared with regard to the relative amounts of organic matter. Particulate and dissolved organic matter were measured in all the lakes and the biomass of zooplankton and macrobenthos measured in the upper three lakes only. The study reveals that, in general, the lakes can be arranged in the order, Superior, Huron, Michigan, Erie, Ontario, with regard to increasing amounts of organic matter in the different categories. This does not seem to hold for the zooplankton. The order of ranking is closely related to the relative concentrations of total dissolved solids in the different lakes and may well be related to their relative states of eutrophication. The amount of dissolved organic matter is shown to be 3 to 10 times larger than the amount of particulate organic matter which, in turn, is much greater than the amounts of zooplankton and macrobenthos.

## INTRODUCTION

In order to gain a thorough understanding of the biology of the Great Lakes, it is necessary to know how biological conditions differ among the lakes. However, the difficulty in sampling all the lakes at approximately the same time has largely prevented comparative studies. Thus, we were pleased to seize an opportunity to carry out such a study in the summer of 1966.

As part of a test of the feasibility of using merchant ships during their normal passage to obtain oceanographic and limnological samples (the Research Ships of Opportunity concept), the senior author was scheduled to sail aboard the merchantman S. S. EXILONA from Detroit, Mich., to Bilboa, Spain. This provided an opportunity to sample in Lakes Erie and Ontario (Robertson 1967) at the same time C. F. Powers was aboard our research vessel INLAND SEAS on the upper three lakes.

We wanted to sample properties that would give a good general comparison of biological conditions and yet be fairly easily measurable under the conditions imposed by the use of an underway merchantman. To satisfy these re-

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[1] This work was supported in part by ONR Project NR 104-818, Contract Nonr-1224(53).

quirements, we decided to measure the amounts of particulate organic matter and dissolved organic matter in the surface waters. The usefulness of these properties for comparing lakes has been well documented in extensive studies by Birge and Juday (1926a, 1926b, 1927, 1934) on Wisconsin lakes. On the research vessel it was possible to take samples for making other measurements: the quantity of zooplankton, macrobenthos, and dissolved and particulate organic matter at depth. The purpose of this paper is to compare the biology of the five lakes, using the results of these investigations.

We wish to acknowledge the assistance of Mrs. Jeanne Rose, Mrs. Sharon Czaika and Miss Mary McCartney with the laboratory analysis of these samples, and Mr. Grant M. Barkley with the sampling aboard the merchantman. Especially, we wish to acknowledge the cooperation of the American Export Isbrandtsen Lines for the use of their ship and the assistance of Captain Lo Re and the officers and crew of the S. S. EXILONA. To these and the many others who freely assisted with this work we extend our thanks.

In addition to its appearance in this report, this paper is being submitted for publication in a technical journal.

## METHODS

The amount of particulate organic matter was determined by the method described by Robertson and Powers (1965). Briefly, this entails filtration on preweighed membrane filters (0.8 micron pore size), drying, weighing, ashing at 600°C, and then weighing the ash. The weight of particulate organic matter is obtained by subtracting the ash weight from the dry weight of the material filtered from the water. On the INLAND SEAS the water to be filtered was obtained from a Nansen bottle cast. The bottles were set every 5 m from the surface to 25 m and at 1/4, 1/2, and 3/4 the distance between 25 m and the bottom. Aliquots of equal volume were taken from each of the top six bottles and filtered through one filter, while aliquots of twice the volume were taken from the lower three bottles and filtered through a separate filter. Thus, two samples for determination of particulate organic matter were obtained at each station, one above and one below the usual level of the thermocline.

On the merchantman the samples were obtained from the main injection line of the vessel, which penetrated the hull at a depth of approximately 24 ft (7.3 m), was 3 ft (0.9 m) in diameter, and passed about 10,000 gal (37,853 l) of water per minute. The samples were drawn from the line in the engine room through copper tubing, allowing several liters to run each time before taking the sample. The samples were treated as outlined above, except only one aliquot was filtered on each filter, since only one depth was sampled.

Determinations of the concentration of dissolved organic matter were made on the water which had been filtered to remove the particulate matter. This water was transferred to polyethylene bottles immediately after filtering and frozen for return to the laboratory. The concentration of dissolved organic matter in each sample was determined by a dichromate oxidation using the method of Maciolek (1962). The factor given by Maciolek to enable the results from the oxidation to be expressed in terms of organic matter was used for this work.

Determinations of the biomass of macrobenthos were made upon samples collected with a Ponar bottom sampler (Powers and Robertson 1967). The organisms in these samples were separated from most of the sediment through elutriation and screening using the device shown by Powers and Robertson (1965). The dry weight of macrobenthic organic matter in each sample was determined by their method, which is a loss on ignition procedure similar to that used for determination of the particulate organic matter.

Samples for determination of the dry weight of zooplankton were collected with a #5 0.5-m plankton net. The collections were made by towing the net vertically from within 5 m of the bottom to the surface. The samples were then washed down with a hose while still in the net, until most of the phytoplankton and other organisms that could be washed through the meshes of a #5 net had been removed. Washing was discontinued when the sample no longer appeared distinctly green or brownish green to the naked eye. This procedure undoubtedly caused the loss of the part of the zooplankton biomass which was in the form of organisms too small to be retained by such a coarse net. However, finer nets clogged so badly with phytoplankton that their use was precluded. Some preliminary studies indicate that this procedure retains roughly 50% of the zooplankton biomass in Lake Michigan. It is felt that while the method is only very approximate it should give an indication of the relative amounts of zooplankton in the different lakes.

After washing, the zooplankton samples were filtered on preweighed "ashless" filter paper (Whatman no. 40) and placed in a desiccator with silica gel for transport to the laboratory. The laboratory procedure entailed a loss on ignition similar to that carried out in determining the amounts of particulate organic matter and macrobenthos. The samples were dried 24 hr at 40-60°C, weighed, ashed at 600°C for 45 min, and the weight of the zooplanktonic organic matter determined for each sample by subtracting the weight of the ash from the weight of the dried zooplankton.

The mysid, Mysis relicta Lovén, was found in both the benthos and zooplankton collections and so presented a problem as to where it should be included. As this organism is usually found in the waters just above the bottom during the day (Beeton 1957), probably neither method samples its population at all satisfactorily. Thus, it was unfortunately deemed necessary for the purposes of this study that Mysis be ignored, and any individuals collected were picked out and discarded.

All sampling was done in triplicate and the average of the three subsamples used as the result from that station. In a few cases one of the triplicates was lost, and the result was based on the remaining two subsamples. The standard deviation has been calculated for each series of subsamples, and these are presented in the tables with the results. The locations of the stations are given in Table 1 and on the map in Fig. 1. Some stations were sampled only for benthos, and these are indicated on the map by open circles.

## RESULTS

### PARTICULATE ORGANIC MATTER

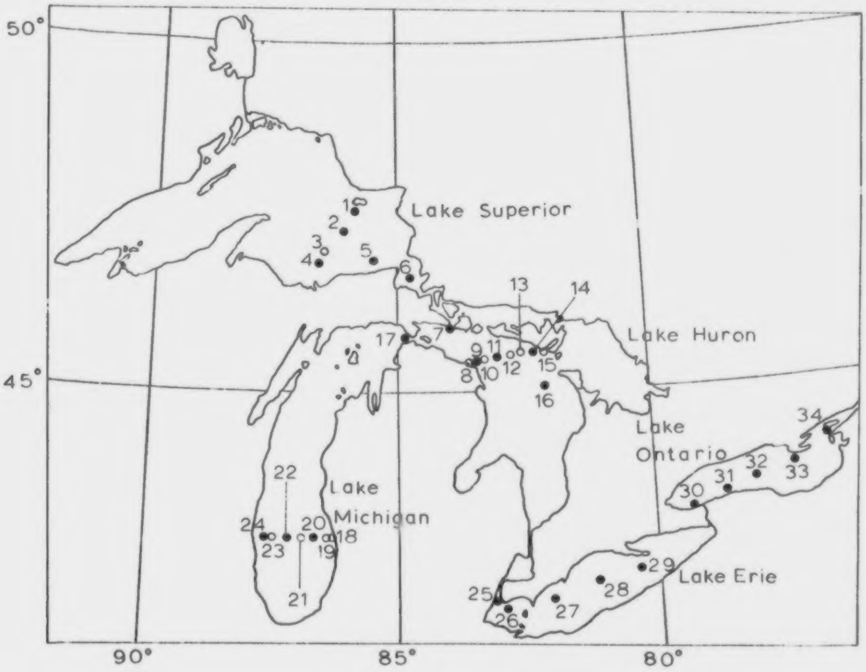
Results from the determinations of amount of particulate organic matter are presented in Table 2. The values for the upper waters are for determinations on material from the 0-25 m depth range in the upper three lakes but only for determinations on material from the depth of the merchantman's water intake in the lower two lakes. Excluding Lake Erie for a moment, the levels of particulate organic matter in the upper waters are distinctly different in the different lakes. The values for Lake Superior are lowest, being from 0.28 to 0.50 mg/l with a mean of 0.42 mg/l. Lake Huron is next with a range of 0.61 to 1.00 mg/l and a mean of 0.71 mg/l, and is followed by Lake Michigan with a range of 1.05 to 1.18 mg/l and a mean of 1.12 mg/l. Lake Ontario has the highest values with a range of 1.09 to 1.68 mg/l and a mean of 1.41 mg/l. Interestingly, by far the highest value in Lake Huron is on the west side of the lake at Station 9, where Ayers _et al_. (1956) found water which apparently had been transported through the Straits of Mackinac from Lake Michigan.

In Lake Erie, in contrast, the results have a much wider spread, ranging from 3.80 mg/l at the mouth of the Detroit River to 0.41 mg/l in the eastern part. The two stations in the shallow western end have by far the highest values found during this study, averaging 3.56 mg/l, while the values in the central and eastern parts of the lake are much lower, averaging 0.68 mg/l. The values decrease consistently from west to east in Lake Erie with the result that the easternmost station has a value at the level found in Lake Superior.

Generally, the amounts of particulate organic matter below 25 m show a pattern that agrees with the results from the surface waters. Lake Superior has the lowest values with a range of 0.20 to 0.40 mg/l and a mean of 0.30 mg/l. Lake Huron has intermediate values with a range of 0.71 to 1.31 mg/l, and a mean of 0.98 mg/l, while Lake Michigan has the highest values with a range of 0.97 to 1.33 mg/l and a mean of 1.15 mg/l. Two stations in Lake Huron have amounts of particulate organic matter in the deep waters within the range for Lake Michigan, 1.11 and 1.31 mg/l.

TABLE 1. Locations of the sampling stations in the Great Lakes.

| Station | Location | | Station | Location | |
|---|---|---|---|---|---|
| | N lat | W long | | N lat | W long |
| 1 | 47°37'54" | 85°49'48" | 18 | 42°49'40" | 86°14'50" |
| 2 | 47°10'30" | 86°16'45" | 19 | 42°49'40" | 86°18'25" |
| 3 | 46°50'12" | 86°28'12" | 20 | 42°49'10" | 86°28'25" |
| 4 | 46°44'00" | 86°32'48" | 21 | 42°48'50" | 86°41'30" |
| 5 | 46°45'48" | 85°31'18" | 22 | 42°49'00" | 86°50'00" |
| 6 | 46°35'36" | 84°49'30" | 23 | 42°47'40" | 87°26'50" |
| 7 | 45°55'10" | 83°51'40" | 24 | 42°47'30" | 87°34'30" |
| 8 | 45°25'12" | 83°41'48" | 25 | 42°04' | 83°08' |
| 9 | 45°25'48" | 83°31'12" | 26 | 41°54' | 82°50' |
| 10 | 45°27'00" | 83°12'12" | 27 | 41°58' | 81°57' |
| 11 | 45°27'54" | 82°56'48" | 28 | 42°12' | 81°04' |
| 12 | 45°28'42" | 82°43'18" | 29 | 42°27' | 80°06' |
| 13 | 45°30'54" | 82°27'06" | 30 | 43°15' | 79°09' |
| 14 | 45°31'30" | 82°16'30" | 31 | 43°27' | 78°25' |
| 15 | 45°32'15" | 82°02'54" | 32 | 43°38' | 77°51' |
| 16 | 45°01'00" | 82°01'00" | 33 | 43°48' | 77°05' |
| 17 | 45°49'00" | 84°48'06" | 34 | 44°06' | 76°21' |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Lake Superior
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Lake Ontario
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FIG. 1. Map showing the sampling stations in the Great Lakes. The open circles show stations where only the macrobenthos was sampled; the filled circles show stations where at least particulate and dissolved organic matter were sampled.

TABLE 2. Comparison of the amounts of particulate organic matter ($\overline{x}$) in the Great Lakes.

| Station | Upper Waters | | Lower Waters | |
|---|---|---|---|---|
| | $\overline{x}$ (mg/l) | Standard Deviation | $\overline{x}$ (mg/l) | Standard Deviation |
| L. Superior | | | | |
| 1 | 0.50 | 0.16 | 0.40 | 0.27 |
| 2 | 0.49 | 0.12 | 0.22 | 0.00 |
| 4 | 0.41 | 0.07 | 0.31 | 0.07 |
| 5 | 0.28 | 0.17 | 0.20 | 0.14 |
| 6 | 0.40 | 0.12 | 0.37 | 0.16 |
| L. Huron | | | | |
| 7 | 0.62 | 0.21 | 1.31 | 0.16 |
| 9 | 1.00 | 0.07 | 0.91 | 0.30 |
| 11 | 0.70 | 0.12 | 1.11 | 0.19 |
| 14 | 0.61 | 0.25 | 0.84 | 0.35 |
| 16 | 0.61 | 0.20 | 0.71 | 0.19 |
| L. Michigan | | | | |
| 17 | 1.18 | 0.49 | -- | -- |
| 20 | 1.05 | 0.35 | 1.33 | 0.33 |
| 22 | 1.12 | 0.42 | 1.14 | 0.45 |
| 24 | 1.13 | 0.25 | 0.97 | 0.10 |
| L. Erie | | | | |
| 25 | 3.80 | --* | -- | -- |
| 26 | 3.32 | 0.54 | -- | -- |
| 27 | 0.95 | 0.33 | -- | -- |
| 28 | 0.69 | 0.00 | -- | -- |
| 29 | 0.41 | 0.07 | -- | -- |
| L. Ontario | | | | |
| 30 | 1.09 | 0.10 | -- | -- |
| 31 | 1.36 | 0.10 | -- | -- |
| 32 | 1.64 | 0.26 | -- | -- |
| 33 | 1.28 | 0.10 | -- | -- |
| 34 | 1.68 | 0.28 | -- | -- |

*No standard deviation because only one subsample available.

TABLE 2. Comparison of the amounts of particulate organic matter ($\overline{x}$) in the Great Lakes.

| Station | Upper Waters | | Lower Waters | |
|---|---|---|---|---|
| | $\overline{x}$ (mg/l) | Standard Deviation | $\overline{x}$ (mg/l) | Standard Deviation |
| L. Superior | | | | |
| 1 | 0.50 | 0.16 | 0.40 | 0.27 |
| 2 | 0.49 | 0.12 | 0.22 | 0.00 |
| 4 | 0.41 | 0.07 | 0.31 | 0.07 |
| 5 | 0.28 | 0.17 | 0.20 | 0.14 |
| 6 | 0.40 | 0.12 | 0.37 | 0.16 |
| L. Huron | | | | |
| 7 | 0.62 | 0.21 | 1.31 | 0.16 |
| 9 | 1.00 | 0.07 | 0.91 | 0.30 |
| 11 | 0.70 | 0.12 | 1.11 | 0.19 |
| 14 | 0.61 | 0.25 | 0.84 | 0.35 |
| 16 | 0.61 | 0.20 | 0.71 | 0.19 |
| L. Michigan | | | | |
| 17 | 1.18 | 0.49 | -- | -- |
| 20 | 1.05 | 0.35 | 1.33 | 0.33 |
| 22 | 1.12 | 0.42 | 1.14 | 0.45 |
| 24 | 1.13 | 0.25 | 0.97 | 0.10 |
| L. Erie | | | | |
| 25 | 3.80 | --* | -- | -- |
| 26 | 3.32 | 0.54 | -- | -- |
| 27 | 0.95 | 0.33 | -- | -- |
| 28 | 0.69 | 0.00 | -- | -- |
| 29 | 0.41 | 0.07 | -- | -- |
| L. Ontario | | | | |
| 30 | 1.09 | 0.10 | -- | -- |
| 31 | 1.36 | 0.10 | -- | -- |
| 32 | 1.64 | 0.26 | -- | -- |
| 33 | 1.28 | 0.10 | -- | -- |
| 34 | 1.68 | 0.29 | -- | -- |

*No standard deviation because only one subsample available.

A comparison of the amounts of particulate organic matter between the two depth ranges shows that the upper waters have higher values at all five stations in Lake Superior. In Lake Huron, on the other hand, this is true at only one of five stations, while Lake Michigan shows the top higher at only one of three stations. Robertson and Powers (1965) found that during the summer of 1964 the upper waters of Lake Michigan usually had slightly higher amounts of particulate organic matter than the lower waters. The amounts were usually below 0.90 mg/l in the upper waters and below 0.80 mg/l in the lower waters. Thus, the results for Lakes Huron and Michigan in the present study seem somewhat anomalous compared with the more extensive results in the 1964 work. It may be that a phytoplankton bloom was just concluding in these lakes during our sampling in 1966, and this caused the general level of particulate organic matter to be high and a large part of the material to be below 25 m.

## DISSOLVED ORGANIC MATTER

Results for the determinations of the dissolved organic matter are shown in Table 3. As with the particulate organic matter, the values for dissolved organic matter in surface waters in the upper lakes represent an average for the 0-25 m depth range, while the values in the lower lakes are only for the depth of the merchantman's water intake. These results show much the same pattern as was found with the particulate organic matter. Lake Superior has generally the lowest values, with a range of 2.22 to 2.98 mg/l and a mean of 2.62 mg/l. Lake Huron has very similar values with a range of 2.52 to 2.91 mg/l and a mean of 2.71 mg/l, while Lake Michigan is next with values from 3.24 to 5.81 mg/l and a mean of 4.91 mg/l. Lake Ontario is highest with a range of 5.85 to 6.53 mg/l and a mean of 6.13 mg/l. Due to technical problems at the start of the voyage on the merchantman, only two measurements were obtained for Lake Erie; neither is in the shallow western end. The two values, 5.82 and 6.01 mg/l, are not relatively low as were the results found here for particulate organic matter, but instead are within the lower part of the range found for Lake Ontario.

Results for the concentration of dissolved organic matter below 25 m show that again Lake Superior has the lowest values with a range of 1.77 to 2.65 mg/l and a mean of 2.25 mg/l. Lake Huron is the next lowest with values from 2.41 to 2.83 mg/l and a mean of 2.72 mg/l. Lake Michigan is highest with a range of 4.51 to 4.77 mg/l and a mean of 4.61 mg/l.

The amounts of dissolved organic matter are quite similar in the two depth ranges but are generally slightly higher in the upper waters. This is true at 4 out of 5 of the stations in Lake Superior, 3 out of 5 of the stations in Lake Huron, and at all 3 of the stations in Lake Michigan. The higher values in the upper waters are probably related to that region's being the zone of active photosynthesis and so of more active metabolism and excretion by phytoplankton.

TABLE 3. Comparison of the amounts of dissolved organic matter ($\overline{x}$) in the Great Lakes.

| Station | Upper Waters | | Lower Waters | |
|---|---|---|---|---|
| | $\overline{x}$ (mg/l) | Standard Deviation | $\overline{x}$ (mg/l) | Standard Deviation |
| **L. Superior** | | | | |
| 1 | 2.70 | 0.34 | 2.35 | 0.07 |
| 2 | 2.98 | 0.66 | 2.65 | 0.42 |
| 4 | 2.66 | 0.64 | 1.77 | 0.07 |
| 5 | 2.22 | 0.00 | 1.89 | 0.12 |
| 6 | 2.55 | 0.28 | 2.61 | 0.30 |
| **L. Huron** | | | | |
| 7 | 2.60 | 0.07 | 2.74 | 0.32 |
| 9 | 2.90 | 0.47 | 2.78 | 0.28 |
| 11 | 2.63 | 0.10 | 2.83 | 0.17 |
| 14 | 2.91 | 0.77 | 2.82 | 0.07 |
| 16 | 2.52 | 0.17 | 2.41 | 0.46 |
| **L. Michigan** | | | | |
| 17 | 3.24 | 0.29 | -- | -- |
| 20 | 5.57 | 0.79 | 4.77 | 1.22 |
| 22 | 5.02 | 0.25 | 4.51 | 0.70 |
| 24 | 5.81 | 0.97 | 4.55 | 0.20 |
| **L. Erie** | | | | |
| 27 | 5.82 | 0.21 | -- | -- |
| 28 | 6.01 | 0.07 | -- | -- |
| **L. Ontario** | | | | |
| 30 | 6.02 | 0.85 | -- | -- |
| 31 | 6.53 | 0.19 | -- | -- |
| 32 | 6.28 | 0.30 | -- | -- |
| 33 | 5.85 | 0.43 | -- | -- |
| 34 | 5.98 | 0.32 | -- | -- |

ZOOPLANKTON

The biomass of the zooplankton is presented in Table 4. The results are calculated in two ways; in the second column they are in milligrams per sample and in the fourth in milligrams per cubic meter. Neither way is completely satisfactory. The first does not take into account the differences in depth at the different stations, so, of course, the deeper stations usually have higher amounts of zooplankton. The second way takes depth into account but ignores the fact that most of the zooplankters are found in the upper layers in the Great Lakes (Wells 1960). Thus, with this method the shallower stations tend to have higher amounts because larger proportion of their depth is in the densely populated zone.

TABLE 4. Comparison of the amounts of zooplankton in the upper three Great Lakes.

| Station | $\bar{x}$(mg/sample) | Standard Deviation | $\bar{x}$ (mg/m$^3$) |
|---|---|---|---|
| L. Superior | | | |
| 1 | 187.5 | 47.2 | 2.37 |
| 2 | 250.0 | 102.1 | 0.96 |
| 4 | 195.2 | 14.1 | 1.48 |
| 5 | 247.9 | 83.9 | 2.61 |
| 6 | 141.5 | 43.7 | 1.86 |
| L. Huron | | | |
| 7 | 153.8 | 32.7 | 5.16 |
| 9 | 128.7 | 12.0 | 2.52 |
| 11 | 257.1 | 53.5 | 3.81 |
| 14 | 82.9 | 3.8 | 1.46 |
| 16 | 165.7 | 9.4 | 0.92 |
| L. Michigan | | | |
| 17 | 71.6 | 6.4 | 2.76 |
| 20 | 38.8 | 29.1 | 0.62 |
| 22 | 112.1 | 94.7 | 0.88 |
| 24 | 69.1 | 1.9 | 1.63 |

Because of these problems, it is very difficult to make any statements concerning the relative amounts of zooplankton in the lakes. If the data in terms of milligrams per liter are plotted versus depth, the results show the shallow stations tending to have the expected higher values (Fig. 2). Be-sides this, there seems to be some tendency for the values from Lake Michigan to be lower than those from the other lakes at comparable depths. As the results are so difficult to interpret and as the horizontal distribution of the zooplankton is well known to be extremely irregular, these few results can really only be used to give a rough idea of the magnitude of the organic matter in the zooplankton.

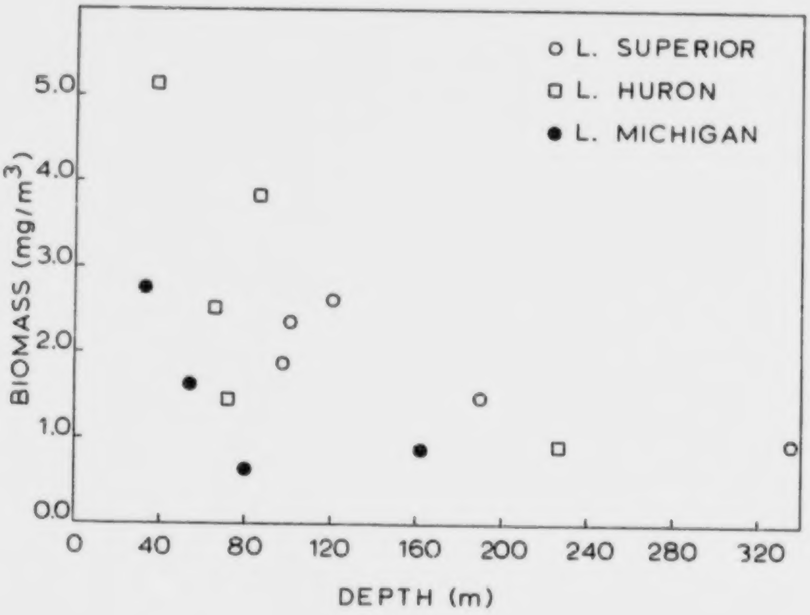

FIG. 2. The zooplankton biomass plotted against sampling depth for the three upper lakes.

## MACROBENTHOS

The amounts of macrobenthos found in the upper three lakes are shown in Table 5. A direct comparison of the range and mean for each lake is almost meaningless, however, for the stations were at different depths in the different lakes; and Powers and Robertson (1965) have shown for Lake Michigan that benthic biomass is very strongly related to depth. Thus, to compare the amounts of benthos in the different lakes, it is necessary to take depth into consideration. To do this the biomass at each station has been plotted against the depth at the corresponding station and the points separately connected for each lake (Fig. 3). The lines for the different lakes do not cross, indicating that the benthic biomass differs consistently between the lakes even at the same depth. The order agrees with that found for particulate and dissolved organic matter with Lake Superior lowest, Lake Huron intermediate, and Lake Michigan the highest of the upper lakes.

TABLE 5. Comparison of the amounts of macrobenthos ($\bar{x}$) in the three upper Great Lakes.

| Station | Depth (m) | $\bar{x}$ (g/m$^2$) | Standard Deviation |
|---|---|---|---|
| L. Superior | | | |
| 1 | 101 | 0.26 | 0.17 |
| 2 | 335 | 0.03 | 0.01 |
| 3 | 134 | 0.07 | 0.03 |
| 4 | 190 | 0.03 | 0.02 |
| 5 | 121 | 0.13 | 0.04 |
| 6 | 97 | 0.33 | 0.09 |
| L. Huron | | | |
| 7 | 38 | 1.96 | 0.10 |
| 8 | 21 | 0.41 | 0.18 |
| 9 | 65 | 1.93 | 0.47 |
| 10 | 102 | 1.18 | 0.14 |
| 11 | 86 | 1.91 | 0.17 |
| 12 | 141 | 0.54 | 0.22 |
| 13 | 123 | 0.90 | 0.40 |
| 14 | 72 | 1.52 | 0.27 |
| 15 | 27 | 0.53 | 0.16 |
| 16 | 227 | 0.17 | 0.11 |
| L. Michigan | | | |
| 18 | 25 | 16.10 | 3.58 |
| 19 | 53 | 6.70 | 0.28 |
| 20 | 80 | 2.66 | 0.42 |
| 21 | 100 | 2.03 | 0.96 |
| 22 | 162 | 0.91 | 0.17 |
| 23 | 100 | 2.77 | 0.43 |
| 24 | 54 | 5.64 | 0.17 |

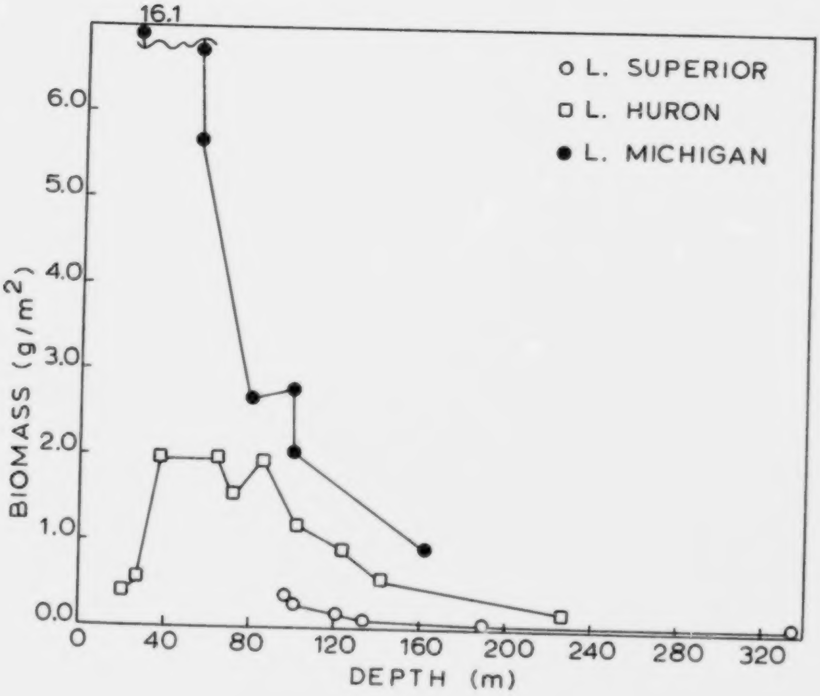

FIG. 3. The macrobenthos biomass plotted against sampling depth for the three upper lakes.

## DISCUSSION

### ARRANGEMENT OF LAKES IN TERMS OF ORGANIC MATTER

This study indicates that the Great Lakes can be generally arranged in the order, Superior, Huron, Michigan, Erie, Ontario, with regard to increasing amounts of organic matter in the different categories studied. This ranking is less sure in Lakes Erie and Ontario, where only the upper layer of dissolved and particulate organic matter could be sampled, than in the upper lakes, where these properties both above and below 25 m as well as macrobenthos and zooplankton were sampled. Excluding the zooplankton, which for reasons already explained presents data which are difficult to interpret, all the results support this order except the particulate matter values from Lake Erie.

The particulate organic matter in Lake Erie seems to present a special case because of the unusual environmental conditions prevailing in that lake. The very high values in the western end of the lake are undoubtedly due to the effect of human and industrial wastes flowing into the lake from Deteroit

River. These waters include large amounts of settleable solids and also high concentrations of certain plant nutrients. The western end is very shallow, which limits dilution of the nutrient enriched waters and makes the light conditions favorable for a phytoplankton bloom through most of the water column. The reason for the drastic decrease in amounts of particulate organic matter in the rest of the lake is less certain. It may be that the bloom in the western end ties up most of some vital nutrient, and so production is greatly restricted downstream from the bloom. Carr (1962) shows that there is oxygen depletion in the bottom waters over extensive areas of the lake during part of the year. This may impede the regeneration of vital nutrients locked up in the organic matter which has settled to the bottom as the organisms in the bloom die off.

## RELATIONS TO EUTROPHICATION

Beeton (1965) presents convincing evidence that the St. Lawrence Great Lakes are experiencing accelerated eutrophication due to man's activities. This implies an increase in the concentration of nutrients and a consequent increase in biological productivity. It is impossible to establish this directly, for there is no information on the past levels of productivity.

Several studies have presented support for increased productivity by showing that the abundance of certain organisms has increased in recent years. Davis (1964, 1965) shows that the phytoplankton has increased in Lake Erie at Cleveland, and Damann (1945, 1960) shows the same for Lake Michigan at Chicago. Bradshaw (1964) presents evidence that the microcrustaceans have increased in Lake Erie, while Robertson and Alley (1966) for Lake Michigan and Carr and Hiltunen (1965) for western Lake Erie show an increase in macrobenthos.

The present study supplies further, albeit indirect, evidence pointing to an increase in productivity accompanying increasing eutrophication. The order of the lakes with regard to amounts of organic matter is also the order of the lakes, as given by Beeton, with regard to increasing amounts of total dissolved solids. This implies a direct relationship between the amounts of organic matter in the different lakes and the dissolved solids, which include plant nutrients. Beeton shows that an increase in the total dissolved solids has been an integral part of the accelerated eutrophication. It seems reasonable to suggest that this has also been accompanied by increased productivity.

In making this suggestion it has been assumed that the order in which the lakes can be arranged with regard to relative amounts of organic matter in the different categories approximates the order in which they fall with regard to productivity. This assumption is based on the postulate that the dissolved organic matter represents material released by actively metabolizing or decomposing phytoplankters and that the amount is directly related to the amount of phytoplankton activity. Further, it is postulated that the organisms included within the categories particulate organic matter, zooplankton, and macrobenthos do not differ substantially in average size between the different lakes, and so the relative rates of production within each of these categories are directly related to the amounts of organic matter.

## RELATIVE AMOUNTS OF ORGANIC MATTER IN THE DIFFERENT CATEGORIES

The amounts of dissolved and particulate organic matter in each lake have been compared by establishing the ratio between the average concentration of these properties for each lake (Table 6). There is always more dissolved organic matter than particulate with the ratios varying from 1:0.11 in the surface waters of Lake Erie to 1:0.36 in the below 25-m waters in Lake Huron. They undoubtedly vary in relation to the present and past phytoplankton productivity as well as other factors such as temperature, light, etc. However, our results indicate that in general the amount of particulate organic matter is one-third to one-tenth of that of the dissolved organic matter.

TABLE 6. The ratio of the average concentration of the dissolved organic matter to that of the particulate organic matter for the different lakes.

| Depth Range | Lake | | | | |
|---|---|---|---|---|---|
| | Superior | Huron | Michigan | Erie | Ontario |
| < 25m | 1:0.16 | 1:0.26 | 1:0.23 | 1:0.11 | 1:0.23 |
| > 25m | 1:0.13 | 1:0.36 | 1:0.25 | -- | -- |

When zooplankton and macrobenthos are included in this type of comparison, depth must be taken into consideration, because it bears a strong relation to the concentrations. Not enough measurements were made during this study on these properties to allow the calculation for each lake of an average value that is properly weighted with regard to depth, it is only possible to present ratios separately for each station (Table 7). The ratios in the table have been calculated by converting the results for each category into the amount or organic matter in that category above 1 m$^2$ of lake bottom and comparing the results to that for dissolved organic matter. The values for the zooplankton have been, rather arbitrarily, doubled, for, as mentioned earlier, there is reason to believe our method underestimates the zooplankton biomass by about 50%. For the dissolved and particulate organic matter, the amount over 1 m$^2$ of bottom has been calculated separately for the two depth ranges and the results summed to give the total amount in each category.

TABLE 7. The ratio above 1 $m^2$ of bottom of dissolved organic matter to particulate organic matter, zooplankton, and macrobenthos at a series of stations in the upper three Great Lakes.

| Station | Depth (m) | Particulate Organic Matter | Zooplankton | Macrobenthos |
|---|---|---|---|---|
| | | Ratio of dissolved organic matter to: | | |
| **L. Superior** | | | | |
| 1 | 101 | 1:0.17 | 1:0.0020 | 1:0.0011 |
| 2 | 335 | 1:0.09 | 1:0.0007 | 1:0.0000 |
| 4 | 190 | 1:0.17 | 1:0.0016 | 1:0.0001 |
| 5 | 121 | 1:0.11 | 1:0.0027 | 1:0.0005 |
| 6 | 97 | 1:0.15 | 1:0.0014 | 1:0.0013 |
| **L. Huron** | | | | |
| 7 | 38 | 1:0.32 | 1:0.0039 | 1:0.0195 |
| 9 | 65 | 1:0.33 | 1:0.0018 | 1:0.0105 |
| 11 | 86 | 1:0.36 | 1:0.0028 | 1:0.0080 |
| 14 | 72 | 1:0.27 | 1:0.0010 | 1:0.0074 |
| 16 | 227 | 1:0.29 | 1:0.0008 | 1:0.0003 |
| **L. Michigan** | | | | |
| 17 | 33 | 1:0.36 | 1:0.0017 | -- |
| 20 | 80 | 1:0.25 | 1:0.0002 | 1:0.0066 |
| 22 | 162 | 1:0.25 | 1:0.0004 | 1:0.0012 |
| 24 | 54 | 1:0.20 | 1:0.0006 | 1:0.0203 |

As with the comparison based on the average values, the particulate organic matter is found to be one-third to one-tenth of the dissolved organic matter. The zooplankton shows ratios ranging from 1:0.0039 to 1:0.0002 and thus is always far less than one-hundredth of the dissolved and also much less than the particulate. The macrobenthos has ratios ranging from 1:0.0203 to 1:0.0000 and is in the same general range as the zooplankton. It has higher ratios in the shallow water but is very low in the deepest water. In general, it seems safe to state that there is more dissolved organic matter in the lakes than particulate and more particulate than zooplankton and macrobenthos, with the last two being very roughly equal.

## COMPARISON WITH WISCONSIN LAKES

Birge and Juday (1934) found that dry organic matter in the plankton of 529 lakes in northeastern Wisconsin ranged from 0.23 to 12.0 mg/l with a mean of 1.36 mg/l. They also report that the mean of many samples in Lake Mendota was 1.47 mg/l, while that for 23 other lakes in southeastern Wisconsin was

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| Station | Depth (m) | Ratio of dissolved organic matter to: Particulate Organic Matter | Zooplankton | Macrobenthos |
|---|---|---|---|---|
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| 11 | 86 | 1:0.36 | 1:0.0028 | 1:0.0080 |
| 14 | 72 | 1:0.27 | 1:0.0010 | 1:0.0074 |
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| L. Michigan | | | | |
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1.11 mg/l. In another work (Birge and Juday 1926a) they report values from Mendota ranging from 0.69 to 3.37 mg/l with a mean of 1.45 mg/l and values from 14 other bodies of water in southern Wisconsin ranging from 0.39 to 19.28 mg/l. Among these latter was one sample from Lake Michigan taken in February 1924 and having a value of 1.62 mg/l.

With regard to dissolved organic matter they (1934) found values as high as 55.34 mg/l in northeastern Wisconsin but state that in lakes containing little external (allochonous) organic matter the range is 3.0 to 6.0 mg/l. In Lake Mendota they found values from 8.41 to 17.12 mg/l with a mean of 12.52 mg/l, while in the other waters of southern Wisconsin they report values from 6.45 to 33.28 mg/l. One sample from Lake Michigan gave a value of 7.04 mg/l.

Our values for particulate organic matter seem to fall well within the range for weight of organic matter in the plankton found by Birge and Juday for Wisconsin lakes. As would be expected, our results from the upper Great Lakes are in the low part of the range exhibited by the inland Wisconsin lakes, while Lake Ontario and western Lake Erie show values closer to the mean from Wisconsin. The one value given by Birge and Juday for Lake Michigan is somewhat higher than our mean for that lake. However, as they sampled close to shore and in the winter, there seems no reason to believe that this value is in conflict with our results.

Their values for dissolved organic matter in inland Wisconsin lakes are generally higher than our values, although the range they give for lakes low in allochonous material is very similar to the range for the Great Lakes. The value they give for Lake Michigan is almost double our mean for that lake. Close comparison of our values with theirs for dissolved organic matter is probably unjustified due to differences in method. They use a loss on ignition technique on the dried residue from lake water. This method almost certainly measures a rather different fraction of the constituents of natural water than our wet oxidation method (Hutchinson 1957).

## REFERENCES

AYERS, J. C., D. V. ANDERSON, D. C. CHANDLER and G. H. LAUFF. 1956. Currents and water masses of Lake Huron. Great Lakes Res. Inst., Univ. Mich., Tech. Paper No. 1. 101 p.

BEETON, A. M. 1957. The vertical migration of Mysis relicta in Lakes Huron and Michigan. Ph.D. Thesis, Univ. Mich., 131 p.

__________. 1965. Eutrophication of the St. Lawrence Great Lakes. Limnol. Oceanog., 10: 240-254.

BIRGE, E. A. and C. JUDAY. 1926a. Organic content of lake water. Bull. Bur. Fish., 42: 185-205.

__________, and __________. 1926b. The organic content of lake water. Proc. Nat. Acad. Sci., 12: 515-519.

__________, and __________. 1927. The organic content of the water of small lakes. Am. Phil. Soc. Proc., 66: 357-372.

__________, and __________. 1934. Particulate and dissolved organic matter in inland lakes. Ecol. Monogr., 4: 440-474.

BRADSHAW, A. S. 1964. The crustacean zooplankton picture: Lake Erie 1939-49-59; Cayuga 1910-51-61. Verh. Internat. Verein. Limnol., 15: 700-708.

CARR, J. F. 1962. Dissolved oxygen in Lake Erie, past and present. Proc. 5th Conf. on Great Lakes Res., p. 1-14.

__________, and J. K. HILTUNEN. 1965. Changes in the bottom fauna of western Lake Erie from 1930 to 1961. Limnol. Oceanog., 10: 551-569.

DAMANN, K. E. 1945. Plankton studies of Lake Michigan. I. Seventeen years of plankton data collected at Chicago, Illinois. Am. Midland Naturalist, 34: 769-796.

__________. 1960. Plankton studies of Lake Michigan. II. Thirty-three years of continuous plankton and coliform bacteria data collected from Lake Michigan at Chicago, Illinois. Trans. Am. Microscop. Soc., 79: 397-404.

DAVIS, C. C. 1964. Evidence for the eutrophication of Lake Erie from phytoplankton records. Limnol. Oceanog., 9: 275-283.

__________. 1965. The standing stock of phytoplankton in Lake Erie at Cleveland, Ohio, 1964. Inform. Bull. Planktology Japan, 12: 51-53.

HUTCHINSON, G. E. 1957. A treatise on limnology. Vol. 1. Geography, physics, and chemistry. John Wiley and Sons, N. Y., 1015 p.

MACIOLEK, J. A. 1962. Limnological organic analysis by quantitative dichromate oxidation. Fish. Wildlife Serv., Res. Rept. 60, 61 p.

POWERS, C. F. and A. ROBERTSON. 1965. Some quantitative aspects of the macrobenthos of Lake Michigan. Proc. 8th Conf. on Great Lakes Res., p. 153-159.

__________, and __________. 1967. Design and evaluation of an all-purpose benthos sampler. Great Lakes Res. Div., Univ. Mich. (in this report).

ROBERTSON, A. 1967. Research Ships of Opportunity Program: Project Neptune Limnos. Great Lakes Res. Div., Univ. Mich., Spec. Rept. No. 28, 25 p.

__________, and W. P. ALLEY. 1966. A comparative study of Lake Michigan macrobenthos. Limnol. Oceanog., 11: 576-583.

__________, and C. F. POWERS. 1965. Particulate organic matter in Lake Michigan. Proc. 8th Conf. on Great Lakes Res., p. 175-181.

WELLS, L. 1960. Seasonal abundance and vertical movements of planktonic Crustacea in Lake Michigan. Fish. Wildlife Serv., Fish. Bull., 60(172): 343-369.

# PHYTOPLANKTON POPULATIONS IN THE EXTREME SOUTHERN BASIN OF LAKE MICHIGAN, 1962-1963

E. F. Stoermer and Elzbieta Kopczynska

## INTRODUCTION

The phytoplankton of Lake Michigan, and particularly of the southern basin of the lake, has received the attention of investigators for many years. The literature pertinent to these investigations has been reviewed by Davis (1966). As is true of most areas that have been studied for a considerable period of time, emphasis in the investigations has shifted from purely floristic considerations (Briggs 1872; Thomas and Chase 1887; Skvortzow 1937) to descriptive ecology (Eddy 1927; Ahlstrom 1936; Lackey 1944) and quantitative measurements (Daily 1938; Damann 1945, 1960; Griffith 1955). Numerous investigations have been predicted upon considerations of water quality and pollution control (Baylis and Gerstein 1929; Williams and Scott 1962).

All of the studies so far carried out on the phytoplankton of Lake Michigan have, in common, several areas of deficiency that have never been satisfactorily resolved. The first of these concerns the taxonomy of the organisms involved. Many of the groups common in the phytoplankton of Lake Michigan are notoriously difficult to treat taxonomically. Definitive treatments of some of the dominant groups are entirely lacking, and this is reflected in the confusion of nomenclature that exists between the various publications. As an example, something over 300 taxa of diatoms have been reported from Lake Michigan. Nearly one-third of the names applied are obvious synonyms. Situations such as this lead to much difficulty in attempting to make comparisons between published studies or in comparing current results with previous studies. The second major problem in dealing with the phytoplankton of Lake Michigan is mostly logistic. It becomes increasingly apparent that there is a good deal of local variation in both abundance and species composition of phytoplankton communities throughout the lake. It is therefore necessary to deal with a very large number of samples from a rather large area in order to arrive at any coherent picture of the distribution and abundance of the organisms that account for the primary productivity of the lake. Unless the investigator is blessed with very considerable resources of equipment and talented assitance, the acquisition and reduction of sufficient data becomes prohibitive in terms of both time and finance. Most investigations have, partially for the reasons outlined above, been restricted in scope. The majority have treated only the floras of inshore waters. Those that did deal with the offshore waters usually obtained samples by vertical net hauls which furnish little information about the distribution of the organisms sampled within the water column.

This paper reports a study designed to reach a closer approximation of the distribution and abundance of phytoplankton in the extreme southern basin of Lake Michigan. We felt it is especially important to arrive at some valid extimate of the correspondence of populations at nearshore stations to those in the main basin of the lake. This should logically furnish us with information that will allow assessment of how far nearshore monitoring stations can be trusted to reflect conditions in the entire basin and, by implication, how much may be inferred about the trophic history of the lake from historic collections at nearshore localities. It was also felt desirable to obtain information regarding the distribution of both the total flora and specific entities in the flora throughout the water column. Although vertical distribution has been well studied in other localities, data are lacking for Lake Michigan. We further hoped to develop a reasonable picture of the seasonal succession of the flora insofar as possible.

## METHODS AND MATERIALS

### DESCRIPTION OF STATIONS

The location of the stations sampled is given in Fig. 1. The major effort of the investigation was directed toward reference stations 1-4, which give a transect from the nearshore waters just off Chicago well into the offshore waters of the southern basin. These stations were sampled 7 August 1962, 22 August 1962, 26 September 1962, 24 October 1962, 21 April 1962, 22 May 1963, and 8 June 1963. The other stations served as check or control stations and were sampled at less regular intervals. While it would have been highly de-

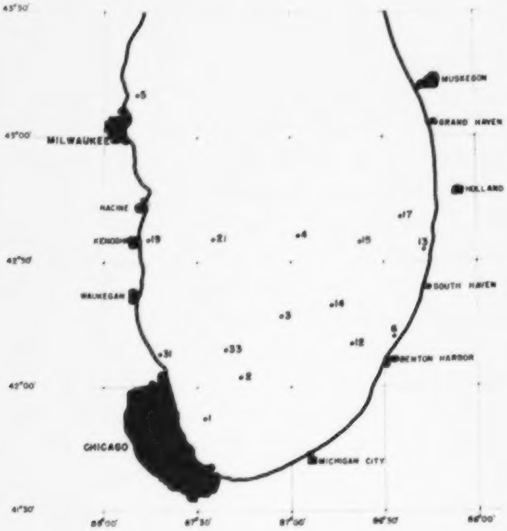

43°30'
MUSKEGON
5
GRAND HAVEN
43°00'
MILWAUKEE
HOLLAND
RACINE
17
KENOSHA
19
21
4
15
13
42°30'
SOUTH HAVEN
WAUKEGAN
14
3
6
12
31
33
BENTON HARBOR
2
42°00'
1
CHICAGO
MICHIGAN CITY
41°30'
88°00'
87°30'
87°00'
86°30'
86°00'

FIG. 1. Outline map of southern Lake Michigan showing location of stations sampled.

sirable to extend the sampling period through the winter months, this was impossible due to the lack of a vessel capable of safe operation during icing conditions.

At shallow stations (1, 5, 6, 13, 19, and 31) samples were taken at three depths approximately equally spaced through the water column. At the deeper stations (2, 3, 4, 12, 14, 15, 17, 21, and 33) four samples were taken, also approximately equally spaced through the water column. Some stations were lost or irregularly sampled due to adverse conditions at the time of sampling. In the following report primary emphasis will be placed on results from stations 1-4 as these stations best illustrate the general tendencies of phytoplankton populations in this part of the lake.

## TREATMENT OF SAMPLES

Samples were collected by Nansen Bottle cast. The 1-liter raw samples were immediately fixed in $I_2KI$ solution or formalin alcohol. Neither method was entirely satisfactory for the preservation of all forms present in the samples. As comparisons of identical samples fixed by the two respective methods showed no outstanding difference in preservation of structure and subsequent facilitation of identification, the formalin alcohol method was used in the later samples as it appeared to give slightly better preservation of samples that were stored for considerable length of time before being counted.

After being returned to the laboratory, the preserved samples were concentrated by settling and stored in 100-ml sealed containers. Prior to analysis the material was resuspended and duplicate aliquots of the concentrated suspension were placed in Utermöhl type combination settling chambers and allowed to settle for 24 hr. The settled samples were examined with a Zeiss inverted microscope under 800 X magnification. Four diameter transects, evenly spaced at 45°, were made across each of the prepared samples and the algae present were identified and counted. Accurate identifications proved to present considerable difficulty for several reasons. Most of the samples contained a considerable amount of detritus. This interfered with identification and counting in that it both tended to hide the algal cells and contributed to a layer on the cover glass of the counting chamber deeper than the focal plane of the optics used. Such conditions rendered accurate estimates very difficult and extremely tedious. In some instances, the quantity of detritus present entirely prevented satisfactory analysis of the samples. The magnifications used, while as high as practical with the equipment and specimen preparation used, were not sufficient for accurate identifications of many of the entities treated. This situation could be obviated to a great extent in the case of the diatoms in that special preparation for identification could be made from the samples after counting, and identifications made from these preparations related back to the untreated samples with a considerable degree of confidence. Other organisms, particularly the naked flagellate forms of several groups, presented more severe difficulties. Neither the fixations used or the method of observation was entirely satisfactory for the treatment of these entities. In many instances the identity of the organisms that appeared in the counting chamber in a somewhat mutilated condition could be deduced with a fair degree of certainty from previous or current observations of living material or specially prepared collections. In other instances satisfactory identifications, even to the generic level, simply could not be made. For this reason some of the groups, particularly of the smaller flagellates, are grouped together under rather broad, and admittedly taxonomically meaningless, categories in the following report. While this is hardly an ideal situation, it was felt to be more desirable then the alternative of adding more names of questionable validity to the already strained literature.

Because of the great diversity of size and physical form present in the phytoplankton algae, attempts are often made to standardize the method of reporting into units comparable in terms of biomass. Because of the rather large difficulties involved in arriving at accurate measurements of the biomass of the various species of algae present in their several physiological states, we have not attempted to make such calculations for our material. In any case the major point of the present work is to arrive at an estimate of the population dynamics of the phytoplankton. For this reason the units reported are the natural vegetative reproductive unit of the organism involved. For the majority of the species treated here this is the cell. The prime exception to this is found in the blue-green algae belonging to the order Oscillatoriales, where hormogonia were counted because of the obvious impossibility of determining the number of "cells" in a hormogonium (Pankratz and Bowen 1963).

## RESULTS

### TOTAL COUNTS

The first samples were taken 7 August 1962. During this sampling period the highest total counts (Fig. 2) were found at station 4 (1387 cells/ml). At this station and at station 3 the highest total cell numbers appeared to be concentrated at about the level of the thermocline (40-60 ft). At both of these stations the populations were of similar size and the vertical distribution was essentially the same with the exception of the deepest sample. Concentrations below 300 ft were considerably higher at station 3 than at station 4. The minimum concentrations (125 cells/ml) were found at the surface of station 2 with concentrations increasing with depth. Essentially the same conditions prevailed at station 1, although somewhat higher populations were found at the greatest depth sampled.

During the second sampling period (Fig. 2) total cell counts at stations 1 and 2 increased by a factor of 2 with the exception of the deepest sample at station 2 where numbers decreased to about one-third of the total recorded during the previous sampling period. At station 3 the total populations were quite

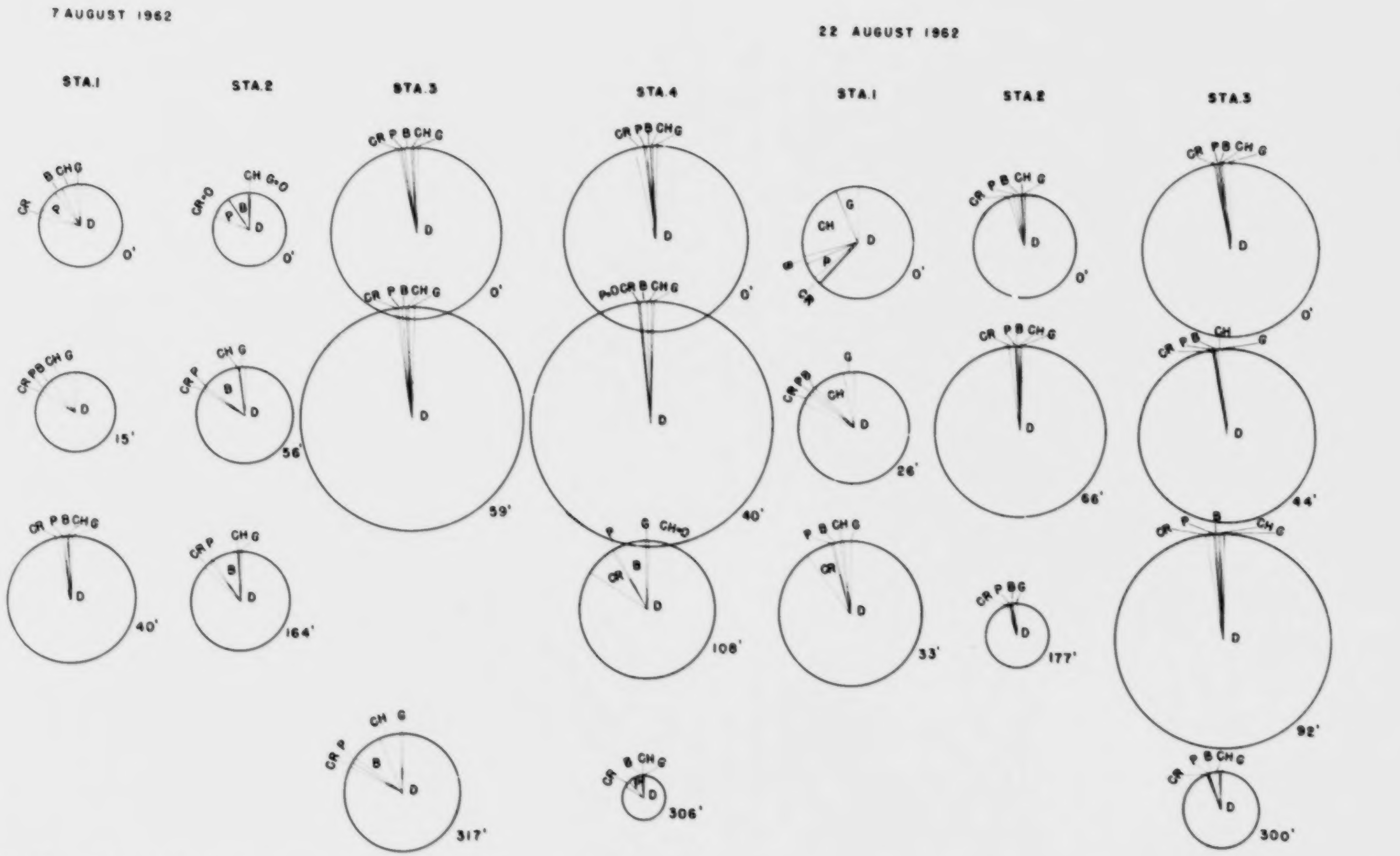


FIG. 2. Relative abundance and percentage composition of phytoplankton populations at stations 1, 2, 3, and 4 on 7 August 1962 and at stations 1, 2, and 3 on 22 August 1962. Area of circles is proportional total numbers per unit volume. Area of segments is proportional to abundance of major algal divisions. D - Bacillariophyta G - Chlorophyta B - Cyanophyta P - Pyrrophyta CR - Cryptophyta, Euglenophyta and unidentified flagellates. Depth of the samples from the surface in feet is indicated below, or to the lower right of each figure.

similar to those found during the previous sampling period, except that the maximum population density was found at still greater depth. No samples were recovered from station 4 during this cruise.

A drastic reduction in total cell counts (Fig. 3) was found in the collections taken on 26 September 1962. The counts at station 1 were only about one-half the total noted at this station during the previous month, while even more drastic total and proportional reductions were found at the offshore stations. Total populations did not exceed 60 cell/ml at any of the depths sampled at the 3 offshore stations. Counts were remarkably uniform throughout all segments of the water column.

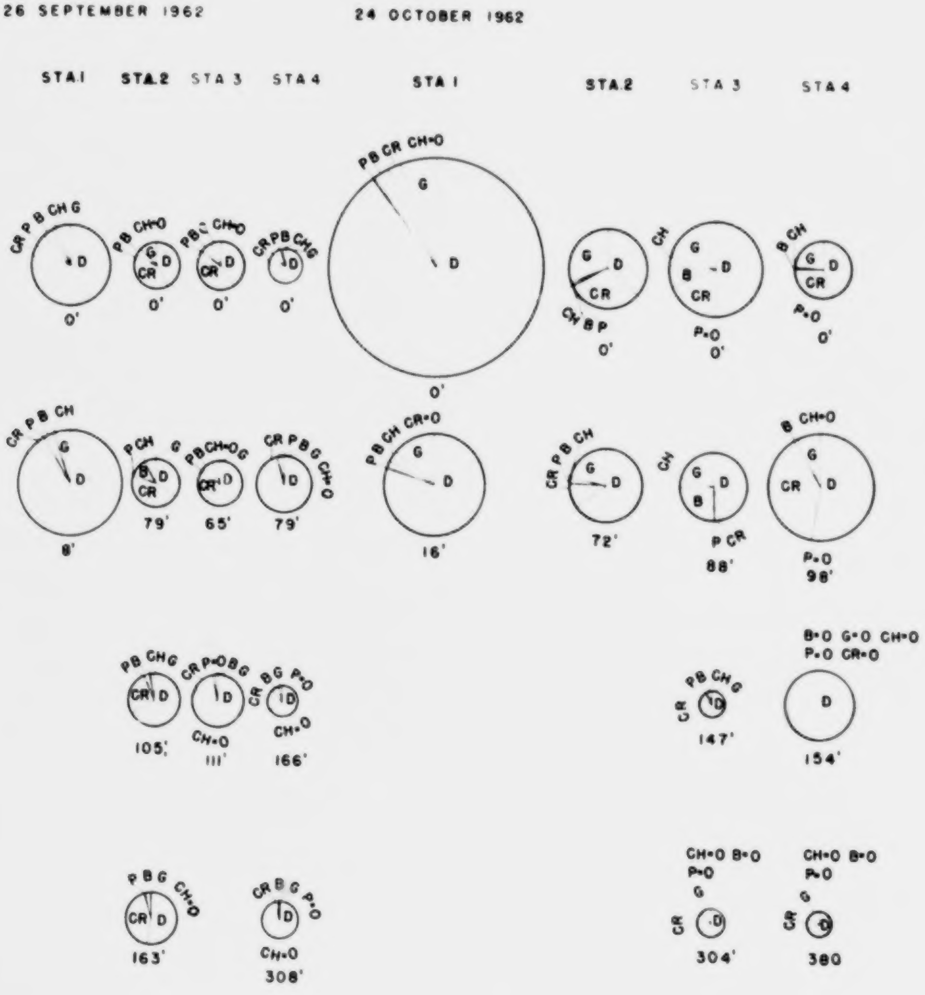


FIG. 3. Relative abundance and percentage composition of phytoplankton populations at stations 1, 2, 3, and 4 on 26 September and 24 October 1962. Labeling as in Fig. 2.

In October the total counts increased at all stations sampled (Fig. 3). There was a 2-3 fold increase in the total cell counts in the upper (<150 ft) portion of the water column. The relatively high proportional contribution of groups other than diatoms, which had first been established during the previous month, was maintained, at least in the upper portion of the water column. A much more drastic increase in total counts was found at station 1, especially at the surface where the total counts increased by a factor of nearly 8 over the numbers recorded the previous month.

The next month for which a complete set of samples was obtained was April 1963. At this time a dramatic increase (Fig. 4) was noted in the total counts at station 1. A total of 2477 cells/ml was recorded in the surface waters, which amounted to a 20 times increase over the low recorded in August and a slightly more than threefold increase over the numbers found in October of the

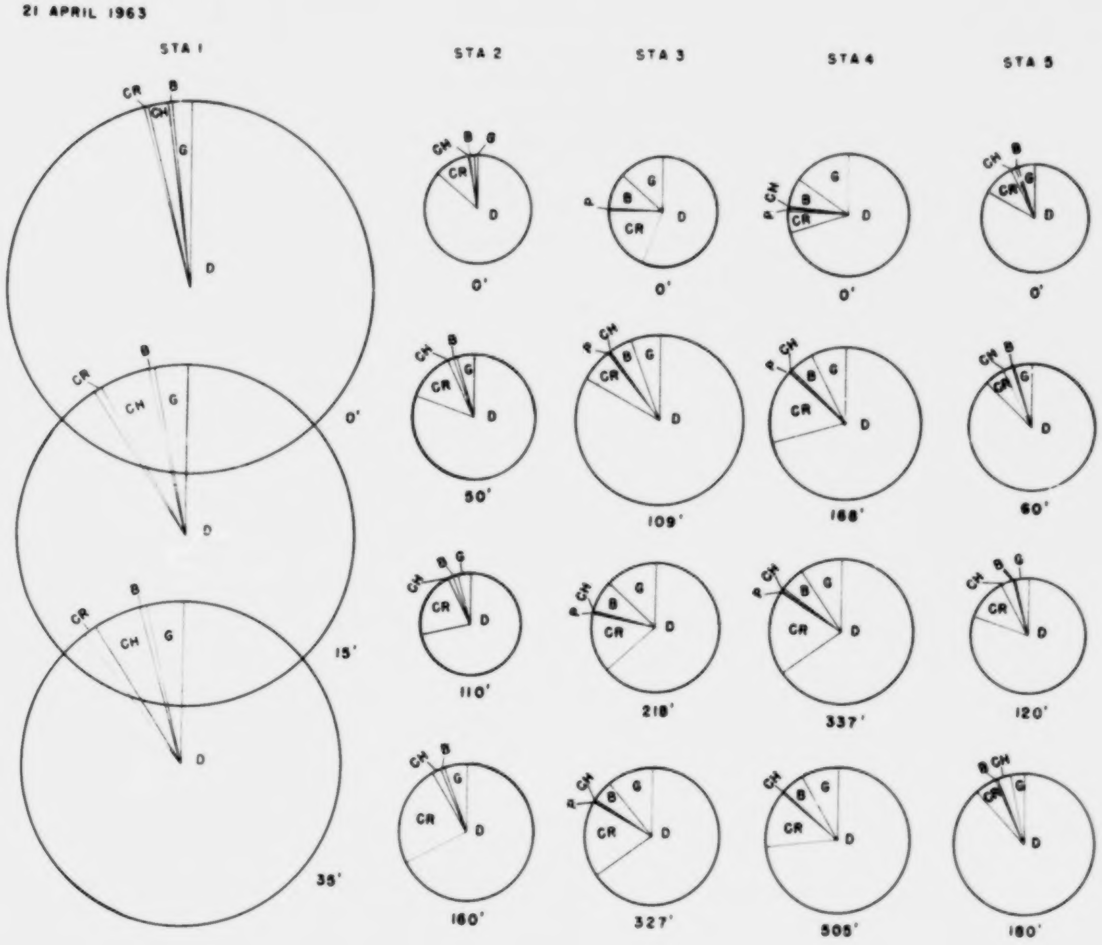


FIG. 4. Relative abundance and percentage composition of phytoplankton populations at stations 1, 2, 3, 4, and 5 on 21 April 1963. Labeling as in Fig. 2.

previous year. The populations at the three offshore stations were remarkably homogenous at all depths sampled. One of the most interesting points is the fact that the populations at station 5, only 3 miles off shore, were more similar to the three offshore stations than they were to the populations at station 1. The populations at this station were, in fact, slightly lower than at any of the three offshore stations. The gross qualitative aspects of the flora at station 5 were, however, more similar to station 1 in that the relatively high proportional dominance of diatoms was maintained and the other major groups were proportionally less well represented than at the offshore stations.

During May there was a further increase in the total cell counts at all depths of all stations (Fig. 5) except the surface sample from station 1, where a very slight decrease in total counts was noted. An increase in numbers was, however, found at the mid-depth sample from this station, giving the highest total found during the study (2770 cells/ml). In contrast to the relatively slight changes at station 1, counts at the offshore stations increased by a factor of 2 to 3 and ranged from 746 cells/ml (163 ft, station 2) to 1170 cells/ml (500 ft, station 4). Contrary to the previous month total counts at station 5 were slightly higher than at the three offshore stations, although still only about half of the totals found at station 1.

In June the total counts (Fig. 6), particularly in the surface waters, were appreciably reduced at station 1. At station 2 the counts at the surface were somewhat reduced but an increase of about a factor of two was found at the 50- and 100-ft sampling depths. The total counts at stations 3 and 4 were essentially identical to those found during the previous sampling period.

## COMPONENT COUNTS

### Bacillariophyta

*Achnanthes* Bory. Most members of the genus grow attached to solid substrates. Several species were found, always in very low abundance, in samples from station 1. *A. clevei* Grun. is the most common member of the genus and appears to be able to exist in the euplankton. It was present in sufficient numbers to be recorded in the counts from station 3 in October and stations 2 and 3 in April.

*Amphipleura* Kütz. *Amphipleura pellucida* Kütz. was the only member of the genus noted in our collections. It most commonly grows in tubular colonies attached to solid substrates but can apparently also exist as single cells in the plankton. The species was very rare in the fall collections and was only noted at the inshore stations. It was also rare in April but became relatively common at all stations during May. In June it was absent from station 1 and only present in the deepest sample from station 2 but remained common at stations 3 and 4.

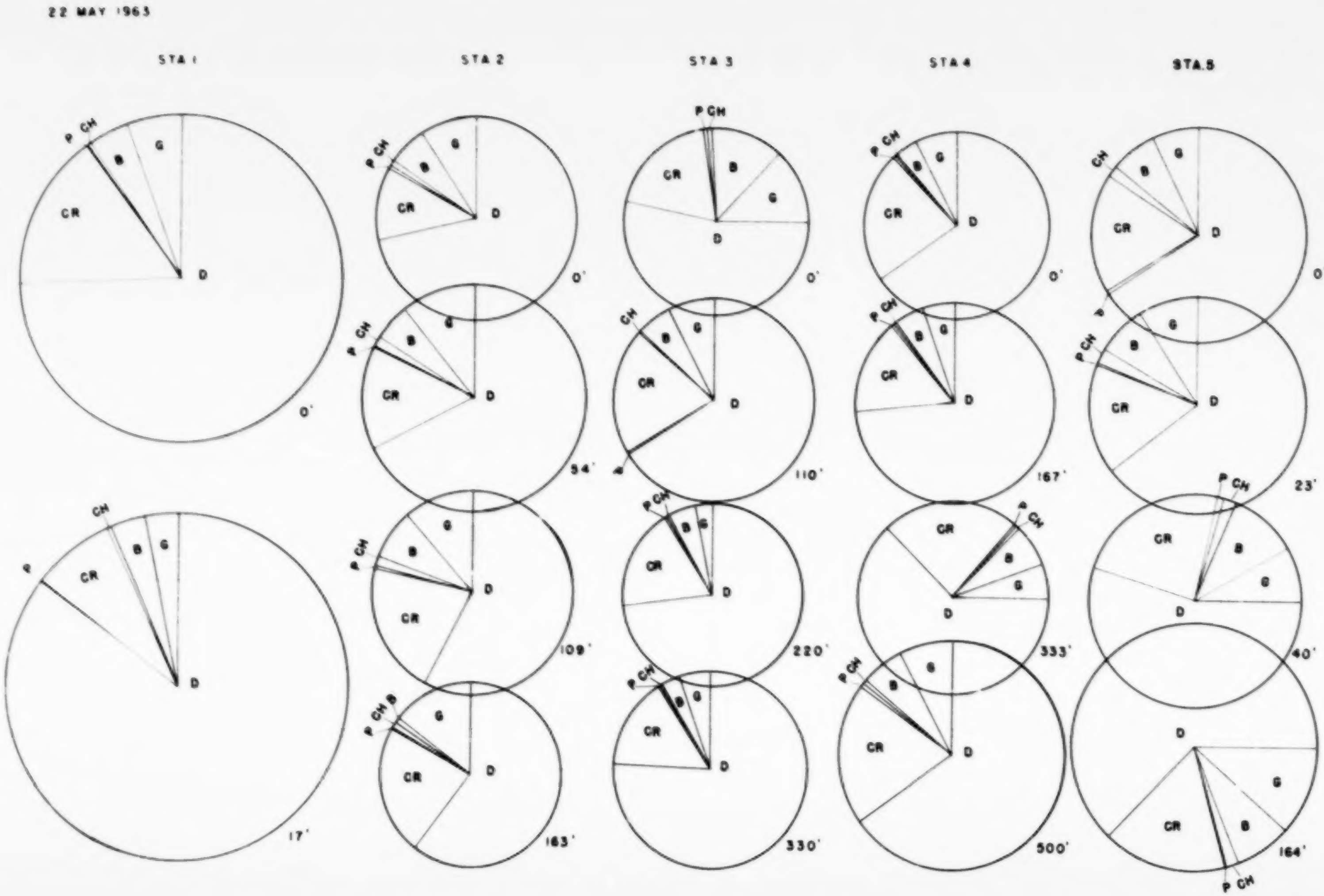


FIG. 5. Relative abundance and percentage composition of phytoplankton populations at stations 1, 2, 3, 4, and 5 on 22 May 1963. Labeling as in Fig. 2.

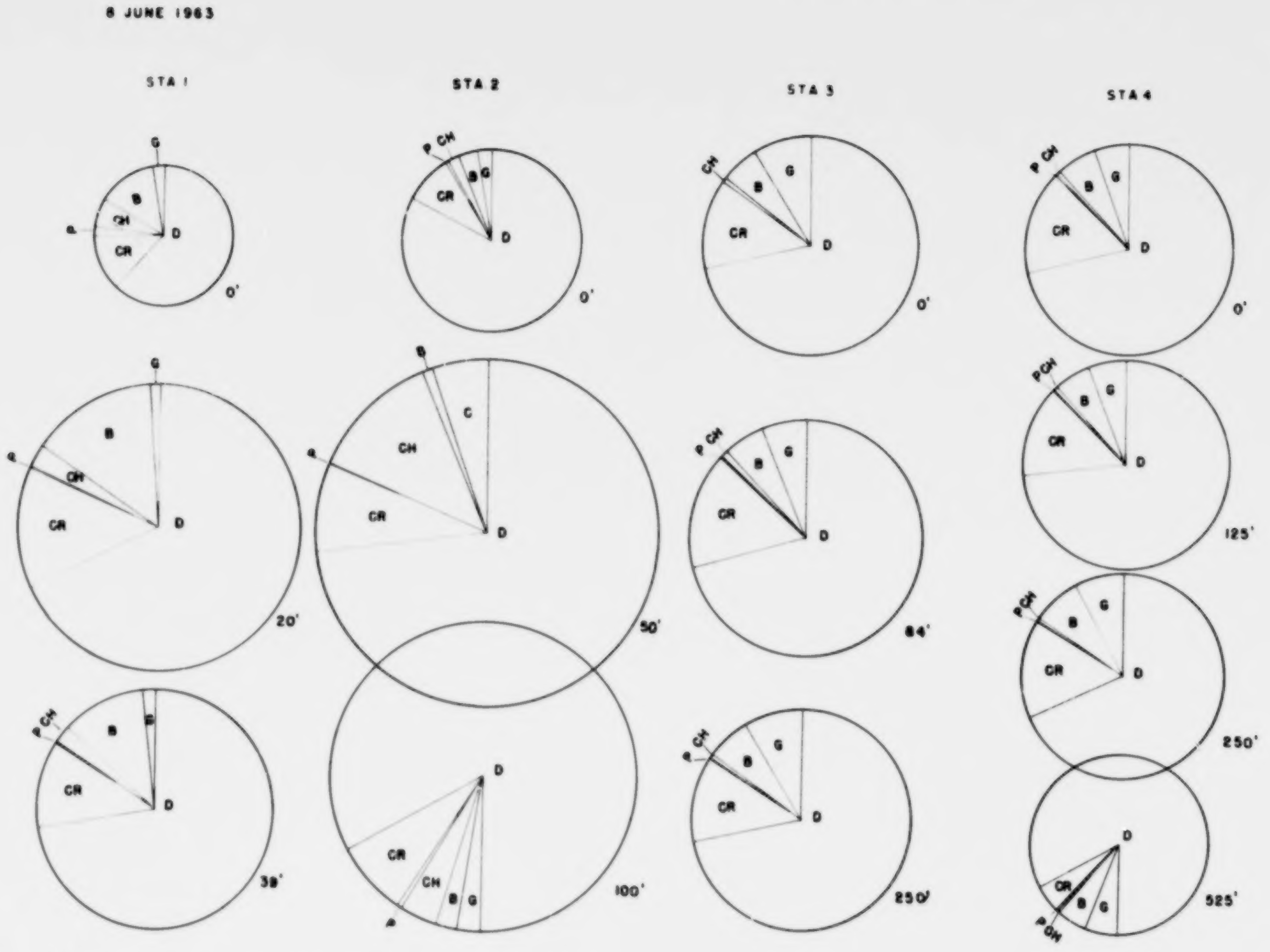


FIG. 6. Relative abundance and percentage composition of phytoplankton populations at stations 1, 2, 3, and 4 on June 8, 1963. Labeling as in Fig. 2.

*Amphiprora* Ehr. *Amphiprora ornata* Bailey was the only species of the genus noted. A few isolated cells were found in fall samples from station 1. A very distinctive entity, probably more widely reported than its actual abundance justifies.

*Amphora* Ehr. Most members of this genus are not euplanktonic. *A. ovalis* Kütz.was found in some fall samples from the inshore stations. *A. ovalis* var. *pediculus* Kütz. was more widely distributed both areally and seasonally but was never present in large quantity. Its unusual distribution is probably to be explained by the fact that it often occurs as an epiphyte on some of the larger euplanktonic diatom species.

*Asterionella* Hassall (Fig. 7). Two members of this genus were recorded. Specimens referred to *A. gracillima* (Hantz.) Heiberg were very rare and their identification is questionable. *A. formosa* Hassall, on the other hand, is one of the major dominants in the flora. It was abundant (ca. 20 cells/ml) in August but declined drastically in September. It became abundant again in October (65 cells/ml) and was present in abundance in all samples taken during the spring.

*Cyclotella* Kütz. (Fig. 8). Several members of this genus were recorded in varying numbers during the period of study. *C. michiganiana* Skv. was the major dominant in the flora during the fall sampling period. The cells in these populations were in the minimum size range for the species. The second most common species in the fall collections was *C. comta* (Ehr.) Kütz. *C. kützingiana* Thw., *C. ocellata* Pant. and *C. stelligera* Cleve and Grun. were also present in most collections in smaller numbers. *C. meneghiniana* Kütz. and *C. pseudostelligera* Hust. were only found at station 1 but were quite common in some samples. The same species were present in the spring collections but the relative abundance of *C. michiganiana* was greatly reduced compared to the other species and the total numbers for the genus as a whole declined despite an increase in the total flora.

*Cymatopleura* Wm. Smith. *Cymatopleura solea* (Bréb.) Wm. Smith, *C. elliptica* (Bréb.) Wm. Smith and *C. cochlea* J. Brun were all present in small numbers at the inshore stations. Isolated individuals were also occasionally noted in samples from the offshore stations.

*Cymbella* Agardh. Isolated individuals of several members of this genus were noted in samples from the inshore stations. These were probably derived from periphyton communities as the vast majority of the species in this genus are not planktonic. A singular exception is found in *C. triangulata* Ehr., which is common in the plankton of northern Lake Michigan and Lake Superior and which was occasionally noted in samples from the offshore stations.

*Diatoma* Bory (Fig. 9). *Diatoma tenue* var. *elongatum* Lyngb. was found to be the most common member of the genus in our collections. Only isolated individuals were found in collections from August, September, and October. It

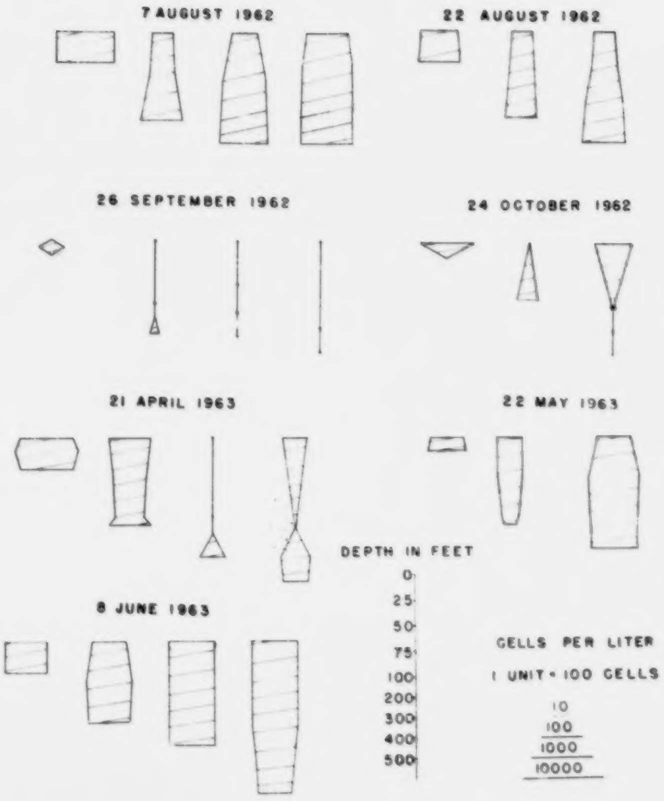


FIG. 7. Vertical distribution of Asterionella spp. at stations 1, 2, 3, and 4 during seven sampling periods as indicated.

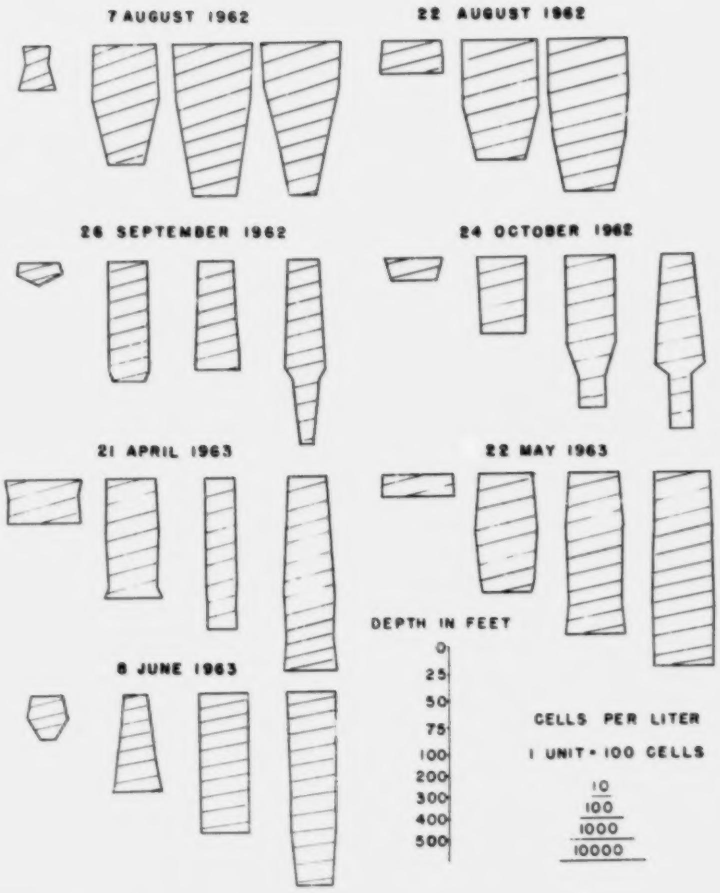


FIG. 8. Vertical distribution of Cyclotella spp. at stations 1, 2, 3, and 4 during seven sampling periods as indicated.

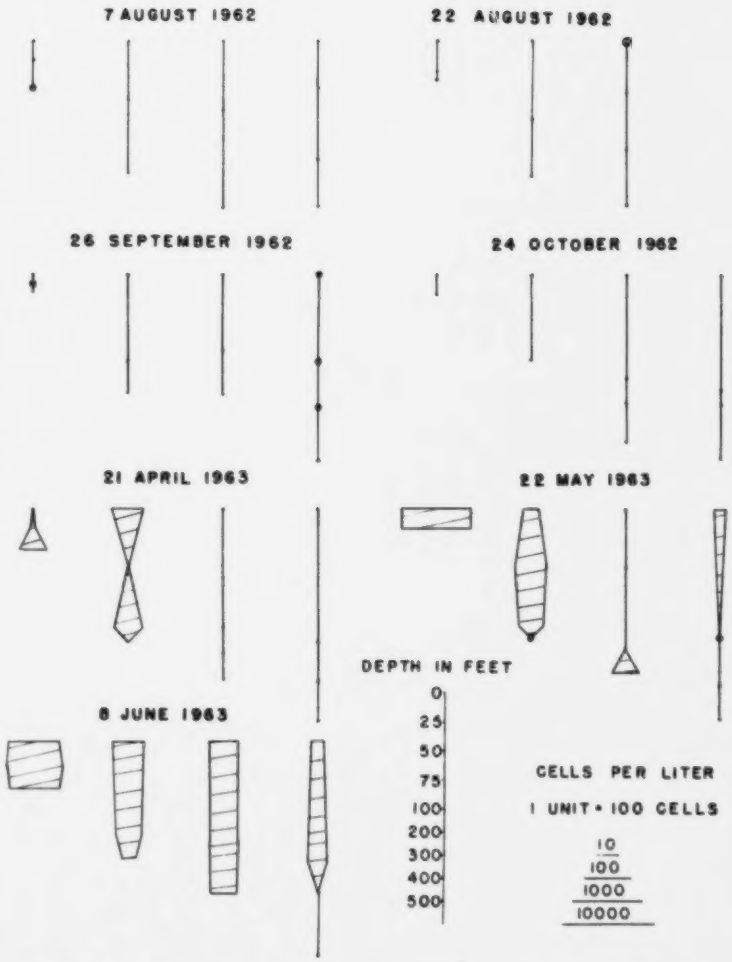


FIG. 9. Vertical distribution of Diatoma spp. at stations 1, 2, 3, and 4 during seven sampling periods as indicated.

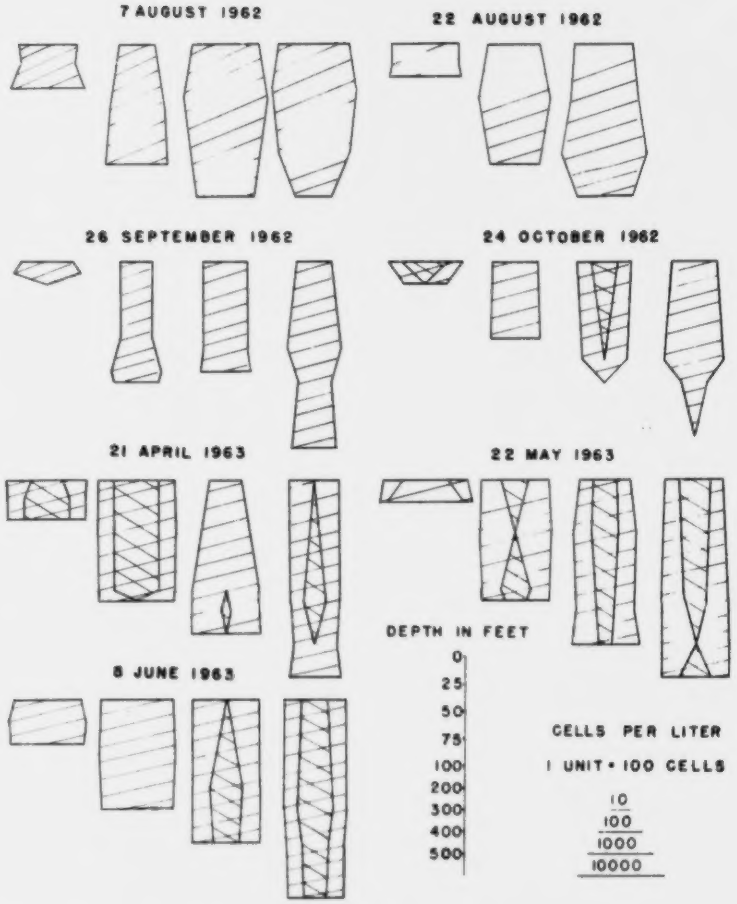


FIG. 10. Vertical distribution of Fragilaria spp. at stations 1, 2, 3, and 4 during seven sampling periods as indicated. Double hatched area is proportional to abundance of species other than F. crotonensis Kitton.

was present at stations 1 and 2 in April, became very abundant at station 1 and began to appear at stations 3 and 4 in May and was abundant at all stations by June. The species is common in polluted harbors and inshore waters around the lake but it appears that only occasional blooms occur in the offshore plankton.

Occasional populations of *D. vulgare* Bory, which usually is found in periphyton communities, were also found at station 1, especially during the fall months.

*Fragilaria* Lyngb. (Fig. 10). During August and September *F. crotonensis* Kitton was the major dominant in the genus at all stations although smaller populations of *F. pinnata* Ehr., *F. leptostauron* (Ehr.) Hust., *F. construens* (Ehr.) Grun. and *F. capucina* Desm. were found at some stations. Beginning in October the relative dominance of *F. crotonensis* was somewhat reduced, although it was still an important component of the total flora, and other species of the genus, particularly *F. capucina* and *F. intermedia* Grun., became relatively more abundant. This transition began at the inshore stations and gradually invaded the offshore stations. The same situation was found in the April and May samples but by June the populations were apparently beginning to return to the situation noted in the fall as nearly pure stands of *F. crotonensis* were found at stations 1 and 2 although stations 3 and 4 still maintained relatively high populations of other members of the genus.

*Melosira* Agardh (Fig. 11). *Melosira islandica* O. Müll. is by far the most abundant member of the genus in the offshore waters of the lake. Occasional populations of *M. granulata* (Ehr.) Ralfs, *M. varians* Agardh, *M. italica* (Ehr.) Kütz. and *M. binderiana* Kütz. were found at the inshore stations. *M. granulata* and *M. binderiana* are the dominant members of the genus in polluted harbors and inshore areas. During the fall sampling season, populations of *Melosira*, consisting almost entirely of *M. islandica*, were restricted to the deeper sampling depths with the exception of populations at station 1 in September and October when this species was present in surface waters in consierable quantity. In April and May the species was present at all stations and at all depths in abundance. By June appreciable numbers of *Melosira* were limited to the deep samples at stations 1 and 2 but the genus was still present in abundance at all depths sampled at stations 3 and 4.

*Navicula* Bory. A large number of species of this genus were noted but the majority appeared as isolated individuals or in very small populations. The only entities present in sufficient numbers to be routinely recorded in the counts were *N. radiosa* Kütz. and *N. radiosa* var. *tenella* (Bréb. ex Kütz.) Grun. These taxa were recorded at least once from all stations studied but were never present in significant quantity.

*Nitzschia* Hassall. A relatively large number of taxa belonging to this genus were recorded during this study. The majority of these were found only at station 1 and are probably derived from the periphyton flora. Several species including *N. holsatica* Hust., *N. recta* Hantz., *N. dissipata* (Kütz.) Grun.,

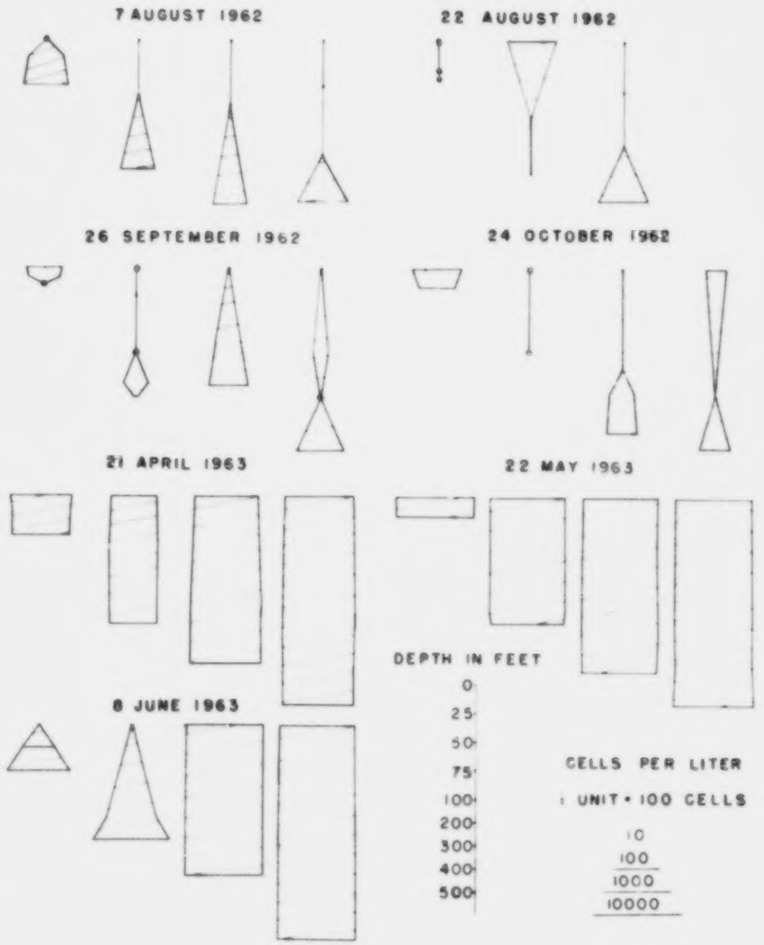


FIG. 11. Vertical distribution of Melosira spp. at stations 1, 2, 3, and 4 during seven sampling periods as indicated.

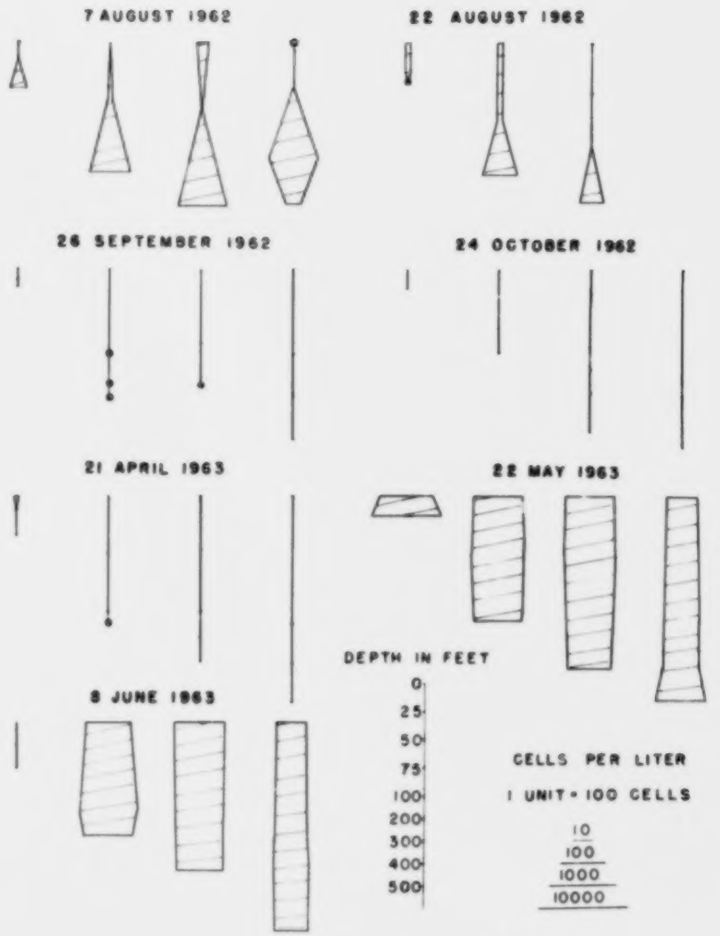


FIG. 12. Vertical distribution of Rhizosolenia spp. at stations 1, 2, 3, and 4 during seven sampling periods as indicated.

*N. fonticola* Grun., *N. vermicularis* (Kützt.) Grun., *N. angustata* (Wm. Smith) Grun., *N. sigmoidea* (Ehr.) Wm. Smith, and *N. bacata* Hust. (?) are quite common in the plankton. Members of this genus, although almost universally present, were not numerically important at any sampling station during the fall period, with the exception of station 1, where *N. holsatica* was present in quantity. Beginning in April they appeared in greater abundance (± 40 cells/ml) at all stations. This situation was maintained through the May sampling period. By June members of the genus were practically absent from station 1 and were only present in the deepest sample from station 2. Populations similar to those found the previous month were still present at stations 3 and 4.

*Rhizsolenia* Ehr. (Fig. 12). *Rhizsolenia eriense* H. L. Smith was the dominant member of this genus in all collections. Small populations of *R. gracilis* H. L. Smith were also occasionally noted. During August populations of *Rhizsolenia* were restricted most to the deeper samples from all stations. During September and October only isolated individuals of *R. eriense* were found in any of the collections. In April a small population was present in the surface waters of station 1, but representatives of the genus were still rare at the other stations. In May relatively high (± 100 cells/ml) populations were present at all depths sampled at all stations. By June these populations had disappeared from station 1 although still present at stations 2, 3, and 4.

*Stephanodiscus* Ehr. (Fig. 13). Although most members of this genus are not a numerically important component of the phytoplankton flora of Lake Michigan, the relatively large size of the individual cells makes them conspicuous and the frequency of reports often outweighs their actual importance. The exceptions to this statement are *S. astrea* var. *minutula* (Kütz.) Grun. and *S. hantzschii* Grun. Neither of these species exceeds about 20µ in diameter and both are largely restricted to eutrophied portions of the lake. *S. hantzschii* is apparently a relatively recent invader which now forms nuisance "blooms" in polluted harbors and inshore waters. The most common members of the genus in offshore collections are *S. transilvanicus* Pant., *S. niagarae* Ehr. and *S. niagarae* var. *magnifica* Fricke. During August, September, and October these species occurred at all stations studied in very low quantities (<1 cell/ml). In April there was a pulse of *S. hantzschii* (160 cells/ml) at station 1 and the numbers of the other species increased to over 1 cell/ml at the three offshore stations. In May no members of the genus were recorded at station 1, although the numbers at the three offshore stations were about the same as in the previous month. In June representatives of the genus were absent from stations 1 and 2 and only occurred in the deepest sample from station 3. *S. niagarae* was present, in slightly increased numbers compared to the previous two months, throughout the water column at station 4.

*Synedra* Ehr. (Fig. 14). Although several members of the genus occur, the only numerically important taxa are *S. ulna* var. *chaseana* Thomas, *S. ulna* var. *danica* (Kütz.) V. H. and *S. acus* Kütz. The former two entities were present in

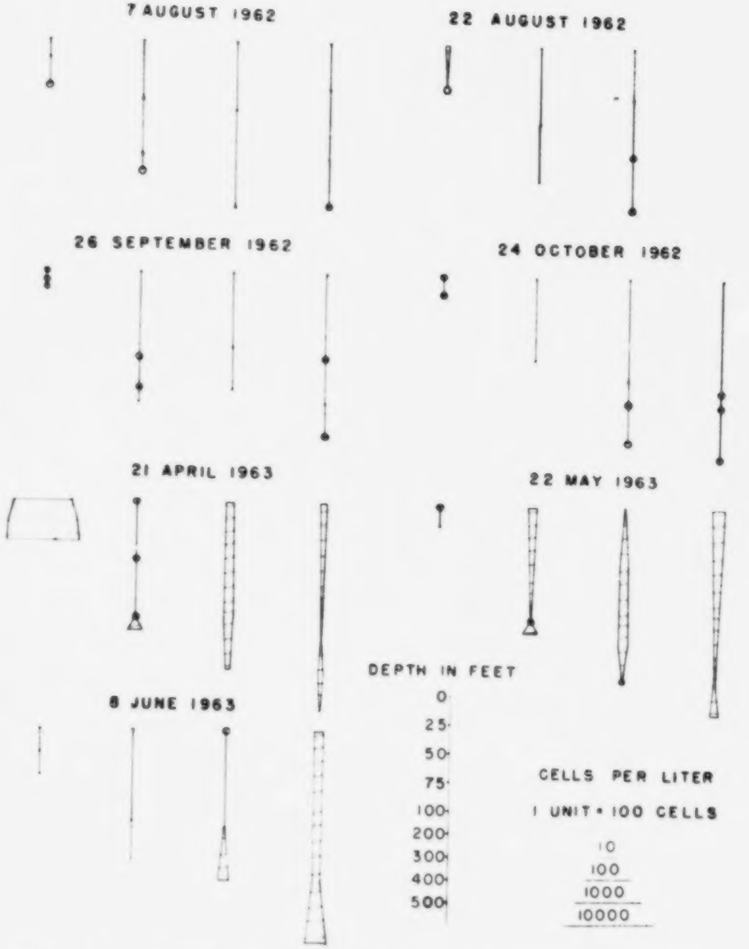


FIG. 13. Vertical distribution of Stephanodiscus spp. at stations 1, 2, 3, and 4 during seven sampling periods as indicated.

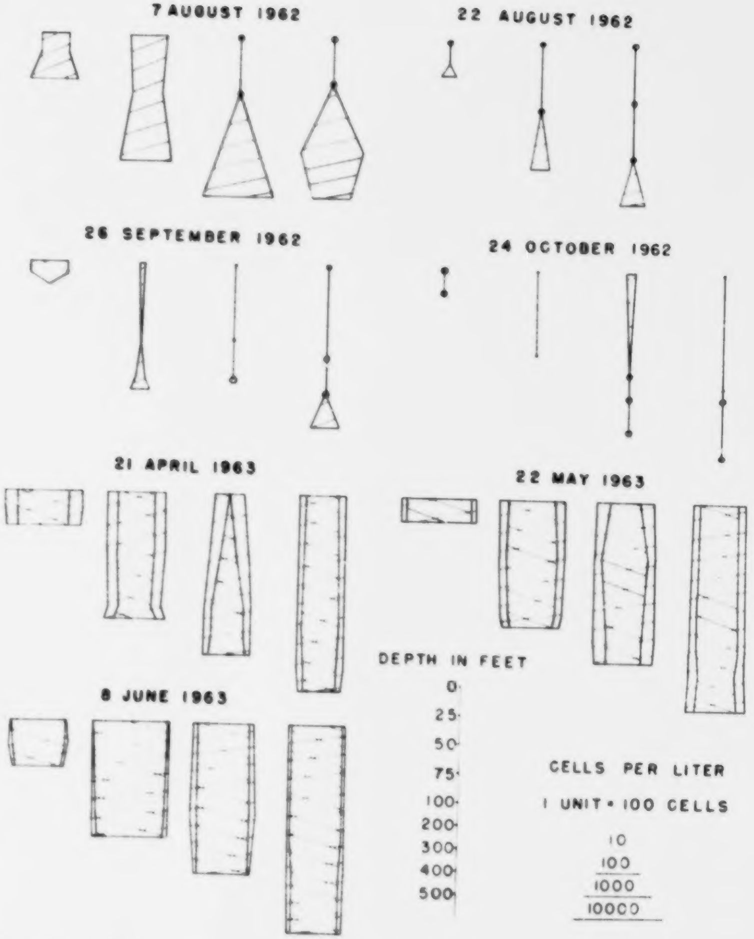


FIG. 14. Vertical distribution of Synedra spp. at stations 1, 2, 3, and 4 during seven sampling periods as indicated. Double hatched area is proportional to abundance of taxa other than S. ulna et var.

quantity (± 10 cells/ml in surface samples, up to 100 cells/ml at greatest depth) in early August and declined in numbers during the succeeding fall sampling periods. In April they were again present in abundance (± 50 cells/ml) at all stations and *S. acus* appeared in significant (± 20 cells/ml) quantities. The populations of these entities remained remarkably constant at all four stations during April, May, and June.

*Surirella* Turpin. Several taxa belonging to this genus were present, always in relatively low abundance. The most common were *S. angustata* Kütz., *S. ovata* Kütz., *S. biseriata* Bréb. and *S. tenera* Greg. Only isolated indidividuals were noted during the fall sampling period. The same low numbers were noted the following April, with the exception of station 2 where members of the genus were recorded from all sampling depths. In May 1-2 cells/ml (mostly *S. angustata*) were found at all depths of the four stations sampled. In June no members of the genus were recorded at stations 1 and 2 but numbers comparable to the previous month were found at all sampling depths at stations 3 and 4.

*Tabellaria* Ehr. (Fig. 15). This genus is the most ubiquitous member of the phytoplankton flora of Lake Michigan. The specific taxonomy is quite confused but most plankton populations are probably to be referred to *T. fenestrata* (Lyngb.) Kütz. et var.

Chlorophyta

Although the green algae constitute a minor fraction of the total cell numbers at the stations studied, the flora is very diverse. During the study 42 taxa belonging to 25 genera were included in the counts. The majority of these occurred only sporadically and in very low abundance. Only the more quantitatively important taxa will be discussed here.

*Ankistrodesmus* Corda. *Ankistrodesmus* spp., primarily *A. falcatus* (Corda) Ralfs, were rare during the fall sampling period. They were abundant enough to be included in the counts (± 1 cell/ml) from the three offshore stations during August but were absent during September and October. Beginning in April 20-60 cells/ml were found at all stations and depths sampled. During May the abundance of members of the genus continued to increase. Highest count recorded was 122 cells/ml in the 50-ft sample from station 2. In June abundance decreased to about the levels noted in April.

*Closterium* Nitzsch. *Closterium acriculare* West was present in August samples in very low (<1 cell/ml) abundance. Only a few isolated specimens were noted during the rest of the fall sampling period. During April, May, and June numbers of this entity increased to an average of about 1 cell/ml at all stations studied with a peak abundance of 12 cells/ml at station 3 in April.

*Kirchneriella* Schmidle. Species of this genus, mostly *K. lunaris* (Kirch.)

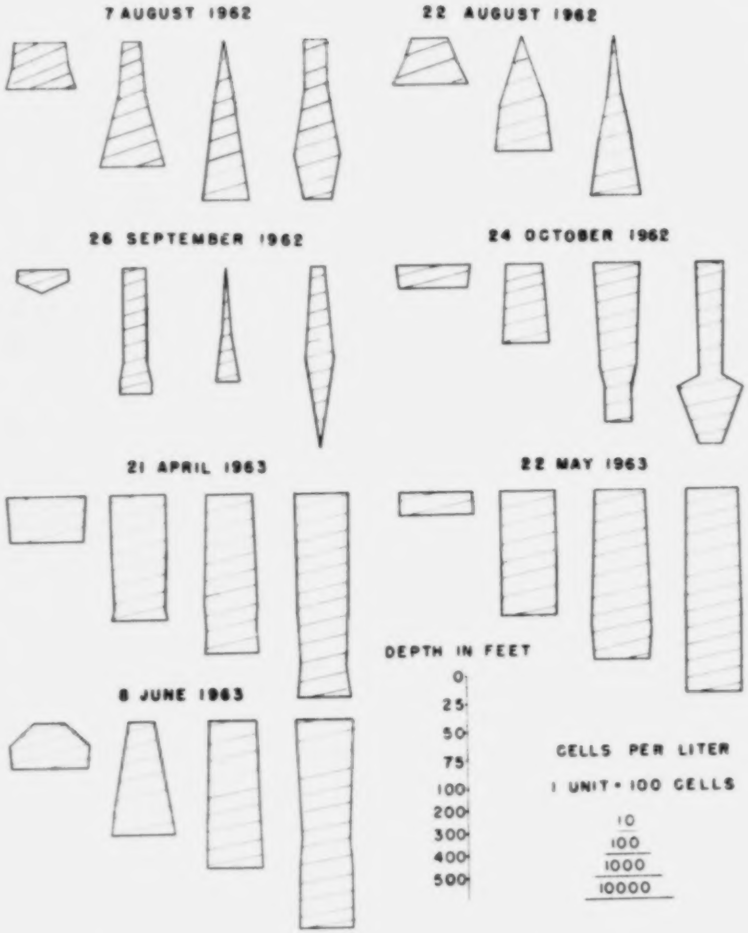


FIG. 15. Vertical distribution of Tabellaria spp. at stations 1, 2, 3, and 4 during seven sampling periods as indicated.

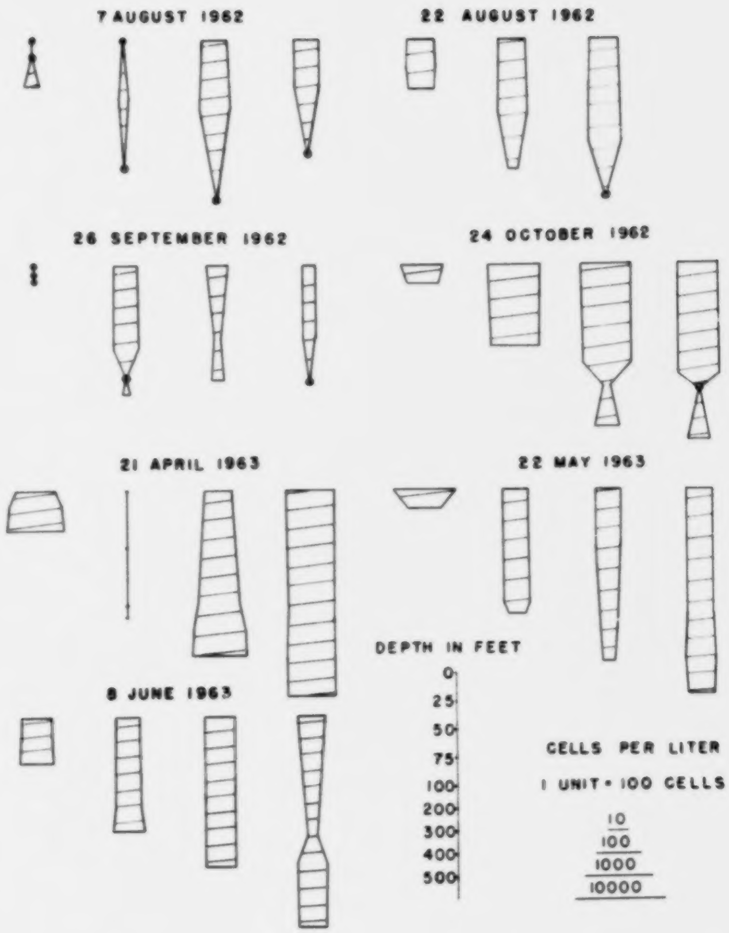


FIG. 16. Vertical distribution of Oocystis spp. at stations 1, 2, 3, and 4 during seven sampling periods as indicated.

Möbius, exhibited the same seasonal trends as the two previously discussed genera. Counts during August averaged 1 cell/ml or less. During April, May, and June representatives of the genus were present in all samples taken with abundance ranging between 1 and 6 cells/ml. One isolated instance of strikingly higher abundance was found in a June sample from the 80-ft depth of station 2 where 58 cells/ml were present.

*Oocystis* Nägeli (Fig. 16). Members of this genus were present at all stations sampled throughout the study with the singular exception of station 2 in April. The three most common species were *O. elliptica* West, *O. submarina*, Lagerh. and *O. lacustris* Chodat. Unlike most entities, members of this genus tended to increase between the August (± 2 cells/ml) and October (± 10 cells/ml) sampling periods. Numbers comparable to those noted in October were found at the 3 offshore stations in April but during May and June decreased to about the levels noted the previous August.

*Tetraedron* Kütz. The seasonal distribution patterns of *Tetraedron* spp. were essentially similar to those of *Oocystis* spp. except that the numbers were generally somewhat lower and showed no marked increase in the spring samples. There was a small pulse at station 1 in October, when up to 24 cells/ml were recorded.

A relatively large number of taxa belonging to such genera as *Coelastrum* Nägeli, *Dactylococcus* Nägeli, *Dictyosphaerium* Nägeli, *Elakatothrix* Willie, *Francia* Lem., *Gloeocystis* Nägeli, *Golerkinia* Chodat, *Lagerheimia* Chodat and *Selemastrum* Reinsch were present throughout the fall sampling period but were not noted in the spring collections. These entities were always present in very low abundance (<5 cells/ml; usually less than 1 cell/ml) and tended to occur as isolated populations rather than showing any defined pattern of occurrence.

## Chrysophyta

*Dinobryon* Ehr. (Fig. 17). This genus is the most important representative of the group in the Lake Michigan plankton. The most common species were *D. divergens* Imhof, *D. cyclindricum* Imhof and *D. sociale* Ehr.

*Mallomonas* Perty. Representatives of this genus were present in low quantities (<2 cells/ml) in August collections from all stations and from stations 1 and 2 in September. It was not noted during other sampling periods except for an isolated pulse (9 cells/ml) of *M. producta* (Zach.) Iwanoff at the surface of station 2 in June.

## Cyanophyta

Species of *Anabaena* Bory, *Aphanocapsa* Nägeli, *Dactylococcopsis* (Reinsch) Hansg., *Aphanothece* Nägeli, *Colosphaerium* Nägeli, and *Microcystis* Kütz. were

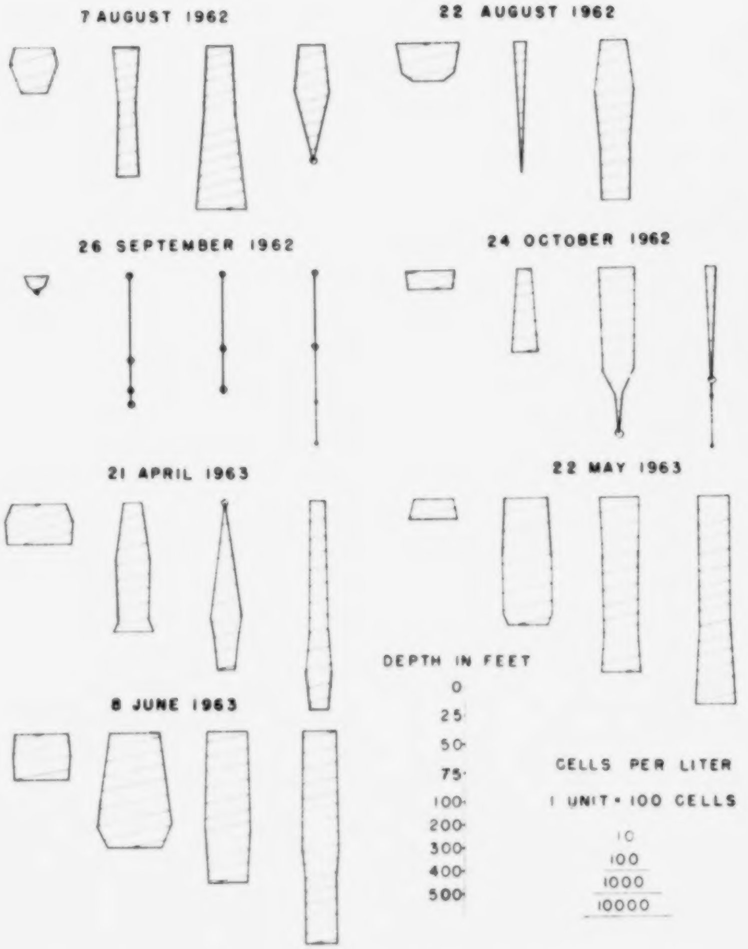


FIG. 17. Vertical distribution of Dinobryon spp. at stations 1, 2, 3, and 4 during seven sampling periods as indicated.

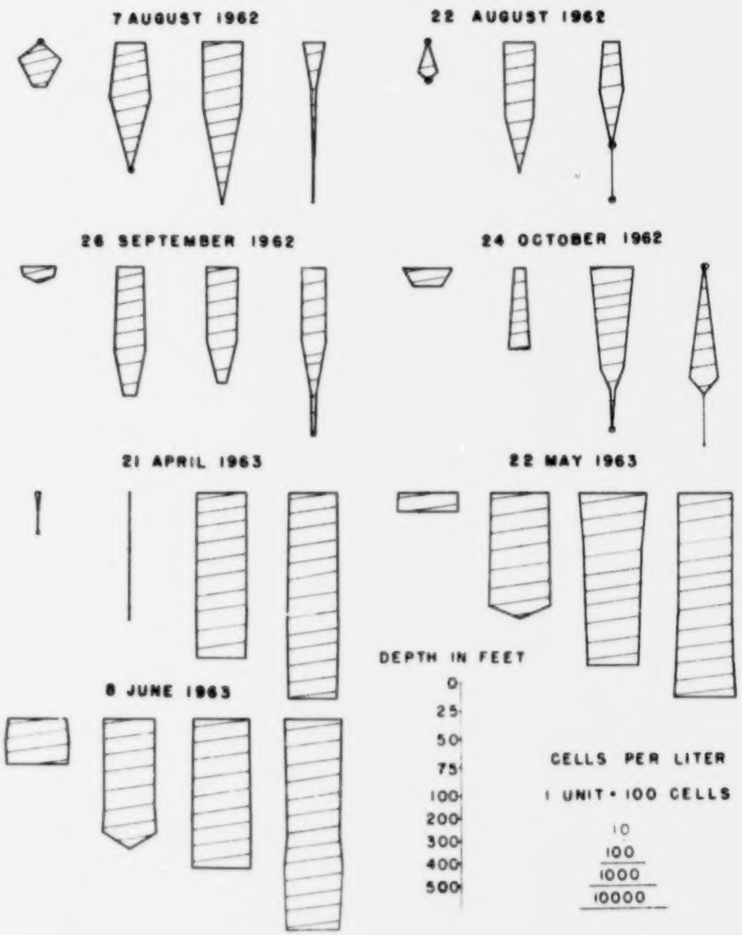


FIG. 18. Vertical distribution of Chroococcus spp. at stations 1, 2, 3, and 4 during seven sampling periods as indicated.

present in low quantities (<5/ml) at most stations during the fall sampling period. All were absent or very rare during the spring.

*Chroococcus* Nägeli (Fig. 18). Species of *Chroococcus* including *C. dispersus* (Keissl.) Lemm., *C. limneticus* Lemm. and *C. minutus* (Kütz.) Nägeli were present in most fall collections in relatively low abundance (<9 cells/ml). In April the genus was absent from stations 1 and 2 but present in quantities up to ten times as great as noted in the fall samples at the other two stations. Similar quantities were found at all stations during May and June.

*Gomphosphaeria* Kütz. *Gomphosphaeria* lacustris Chodat was present in low quantities (<2 cells/ml) at all stations in August but was absent from the September and October samples. Like *Chroococcus* spp. it was absent from stations 1 and 2 in April but was common (± 20 cells/ml) in all samples from the other stations. It was present in all May samples in increased abundance (up to 90 cells/ ml). It was also present in June samples in somewhat lower numbers (± 40 cells/ml).

*Oscillatoria* Vaucher (Fig. 19). *Oscillatoria mougeotii* Kütz. was the only member of this genus common in our collections. During the fall sampling period populations were restricted to the deep samples. Beginning in April small populations (ca. 10 filaments/ml) were found in all samples.

*Spirulina* Turpin. *Spirulina jenneri* (Hass.) Kütz. was found in the bottom water samples from station 1 (4 filaments/ml), 2 (17 filaments/ml), and 3 (30 cells/ml) on 7 August. This is of interest only because abundant occurrence of this organism is often considered to be presumptive evidence of organic enrichment and anaerobic conditions. Only isolated trichomes were found in other fall collections and the organism was not noted in spring collections.

Pyrrophyta

*Ceratium hirundinella* (O.F.M.) Dujardin and *Glenedinium palustre* (Lemm.) Schiller (?) were present in low quantity (<4 cells/ml) at several stations during the fall sampling period. They were not noted in the spring samples.

*Peridinium* Ehr. (Fig. 20). Members of the genus were common in early August (13 cells/ml, station 1) and gradually declined in abundance during the fall sampling season. In April they were again common (7 cells/ml) at station 1 and were present in lower quantities (<2 cells/ml) in scattered samples from the other stations. During May and June, 2-8 cells/ml were present in all samples. *P. tabulatum* Ehr. and *P. wisconsinense* Eddy were the most common members of the genus.

Flagellates (Fig. 21). No specific identifications were attempted on the flagellates in our samples. In the counts they were arbitrarily divided into

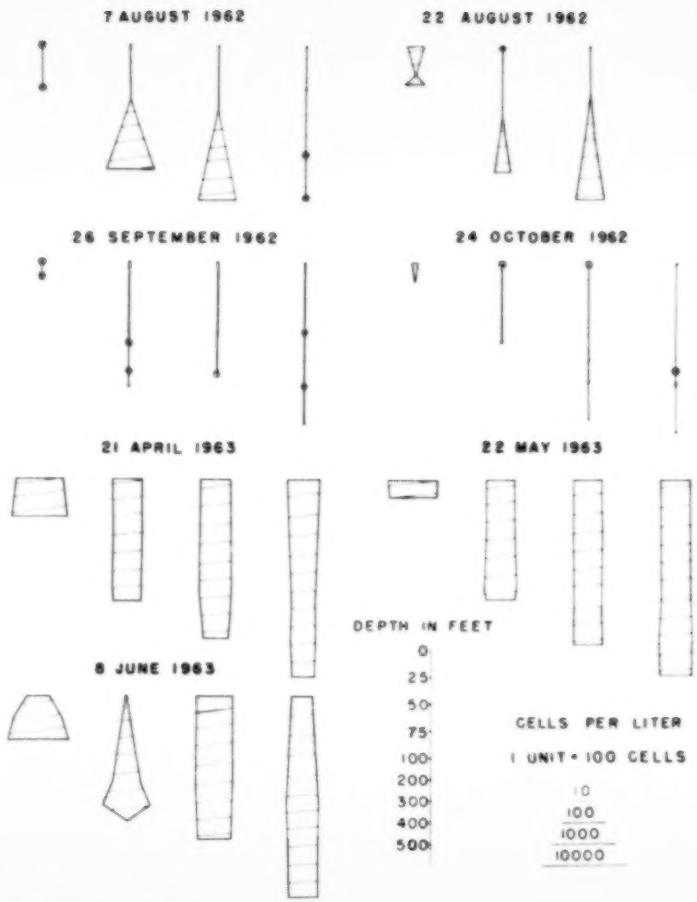


FIG. 19. Vertical distribution of *Oscillatoria spp.* at stations 1, 2, 3, and 4 during seven sampling periods as indicated.

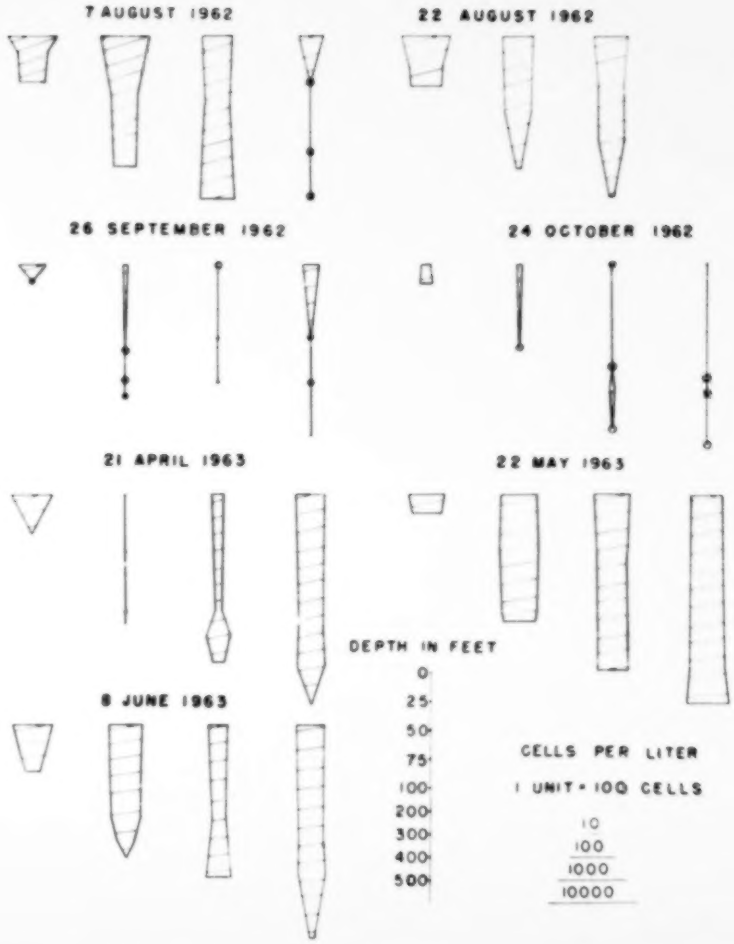


FIG. 20. Vertical distribution of *Peridinium spp.* at stations 1, 2, 3, and 4 during seven sampling periods as indicated.

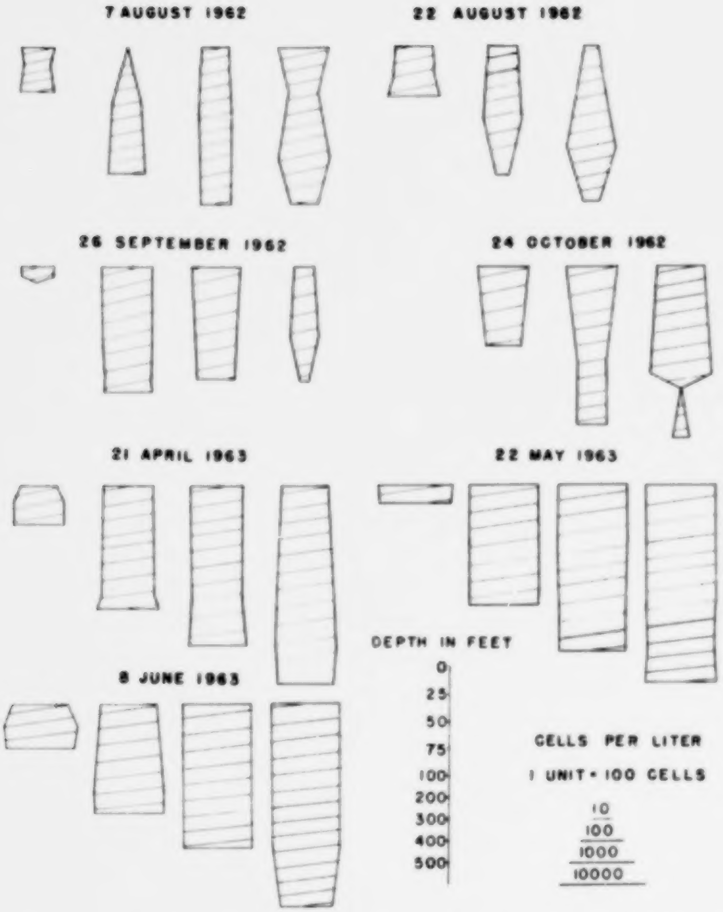


FIG. 21. Vertical distribution of flagellates at stations 1, 2, 3, and 4 during seven sampling periods as indicated.

two groups: the first included the Cryptophyceae and Euglenoids and the second all the generally smaller entities belonging to the other major divisions. The abundance of the entities included in the first group was remarkably stable throughout the sampling period. The small flagellates were a very minor fraction of the total flora during the fall sampling period except for a few isolated pulses (up to 30 cells/ml). Total counts tended to increase from August to October. Throughout the spring sampling period this group of organisms was a considerably more important component of the total flora. Populations varied greatly between stations and between different depths at the same station. No particular pattern was discernible in this variation. During the three spring months sampled, populations exceeded 20 cells/ml in most samples and reached as high as 217 cells/ml in one sample from station 4 in May.

# DISCUSSION

The most striking aspect of the phytoplankton populations at the stations studied is their extremely uniform distribution throughout the water column. This is perhaps to be expected during the spring season before the onset of thermal stratification. It is, however, evident that during this season there must be very active mixing of the water column because it is practically inconceivable that phytoplankton organisms, particularly the more fragile forms, would be recognizable after passively sinking from the lower limit of the euphotic zone to the depth of the deepest samples at the offshore stations. During the fall sampling period there is an evident concentration of total cell numbers at, or just below, the level of the thermocline. It is probable that at least two factors are responsible for this. Undoubtedly the observed concentration can be partially explained on the basis of the difference in rates of settling through the epilimnetic versus the hypolimnetic water because of density differences. If this were the sole factor operative, we should, however, expect to find a more striking difference in total numbers than is observed. Under these conditions we should also expect to find a greater apparent concentration of more resistant forms (such as diatoms) in the samples from below the thermocline. In point of fact quite the opposite tendency is observed. Some of the more fragile forms (particularly the chrysophycean flagellates and blue-green algae) are relatively more abundant in the samples from below the thermocline. It is thus evident that at least some of the species must be actively reproducing in the waters at, or below, the level of the thermocline.

There is a very evident seasonal succession in both numbers and kinds of algae present at the stations studied. It would also appear that one of the most important controlling factors, if not the single controlling factor, in this succession is water temperature. Because of the relatively great thermal inertia of Lake Michigan, it is rather futile to speak of spring and fall blooms in the same context as when referring to smaller and shallower lakes. The situation in the area of study might be compared in some ways to the situation in nearshore marine environments but lacks the complications of salinity gradients and strongly developed current regimes. In any case, our observations indicate that phytoplankton pulses,both in terms of the total flora and in terms of the majority of the individual species, are initiated in the inshore waters and follow the advance of the thermal contours out into the open lake during the spring and early summer. At the moment we cannot accurately assess how much control the spring warming process in the lake exerts on the distribution of mineral nutrients but it is to be suspected that the observed phytoplankton population changes are due to more than a simple correlation with optimal temperature conditions. The October samples suggest that a similar situation may develop with the fall cooling, but our data unfortunately do not extend far enough into the fall period to make any accurate assessment of this situation.

In terms of total numbers, the diatoms are by far the most abundant of the major groups of algae in the phytoplankton of Lake Michigan. As Nalewajko (1966) has pointed out, the relative importance of this group would probably be reduced if standing crop were determined on the basis of ash-free weight rather than cell number. There are, unfortunately, still insufficient published data to make calculation of the biomass contribution of the various elements of the total flora feasible.

Our results indicate that contrary to most previous reports the smaller flagellates are a very important part of the flora in terms of total numbers. As was pointed out previously, the taxonomic disposition of these entities poses a serious problem. On the basis of the relatively few observations we have made on living material, it would appear that the majority of the entities treated in this "catch all" category in the current report would find their true affinities in the Cryptophyceae and Chrysophyceae with a minor fraction placed in the Chlorophyceae. A great deal of further work will be necessary before it will be possible to determine the relative importance of these organisms on the ecosystem.

Our results indicate that the Chrysophyceae, in particular the genus *Dinobryon*, were a considerably less important component of the flora during the period of study than previous reports would indicate.

In both the Chlorophyta and Cyanophyta, the most abundant species followed the same pattern of seasonal succession shown by the more dominant groups. In both groups there were, however, a number of species that tended to reach their maximum development during the late summer and fall when the total flora was at its lowest level. It is apparent from their rather scattered distribution that these species are not particularly well adapted to the present conditions in the waters of the open lake. With further eutrophication of Lake Michigan they can be expected to play a more important role in the ecosystem of the lake in the future.

During the period of study, relatively few species were noted that occurred only at specific stations. One notable example of this was *Stephanodiscus hantzschii*. This organism is apparently a relatively recent introduction to the flora of Lake Michigan. It has been confined primarily to harbors and inshore waters that carry higher nutrient loads than the offshore waters of the lake. During the period of study it was only noted in early spring samples from station 1. This spring (1967) it appeared in substantial numbers from offshore stations over most of the southern basin of Lake Michigan.

Aside from a few cases like the one cited above, there is little evidence of species being selectively excluded from any of the sampling stations during the entire period of study. Although there may be very striking differences in the per volume quantity of phytoplankton present in the inshore versus the offshore stations at a particular sampling interval, our data tend to show that these differences are attributable, in large part, to the timing of seasonal succession at the different stations rather than to large differences in the total populations on a yearly basis. The total differences in apparent standing crop become even smaller if the number of cells in the entire water column is considered.

There is a very striking difference in the total numbers of phytoplankton organisms between the inshore stations in the extreme southern basin of the lake and station 5 just north of Milwaukee. Damann (1966) has pointed out that phytoplankton populations sampled at the Milwaukee filtration plant tend to show one seasonal maximum rather than the bimodal maximum apparent at Chicago. Our observations would tend to indicate that the populations in the Milwaukee area are much more similar to those in the main water mass of Lake Michigan than those in the inshore area near Chicago. The populations sampled at station 5 were quantitatively more similar (for a given sampled date) to the offshore stations and reflected the same seasonal trends as did the offshore populations. It would appear, from our observations, that the unimodal maximum is the more general case for the majority of the lake basin and that the bimodal peak shown at Chicago is the result of special circumstances in this particular area.

## REFERENCES

AHLSTROM, E. H. 1936. The deep-water plankton of Lake Michigan, exclusive of the Crustacea. Trans. Amer. Microscop. Soc., 55: 286-299.

BAYLIS, J. R., and H. H. GERSTEIN. 1929. Micro-organisms in the Lake Michigan water at Chicago. Municipal News and Water Works, 76: 291-296.

BRIGGS, S. A. 1872. The Diatomaceae of Lake Michigan. The Lens 1: 41-44.

DAILY, W. A. 1938. A quantitative study of phytoplankton of Lake Michigan collected in the vicinity of Evanston, Illinois. Butler Univ. Bot. Studies, 4: 65-83.

DAMANN, K. E. 1945. Plankton studies of Lake Michigan. I. Seventeen years of plankton data collected at Chicago, Illinois. Amer. Midland Natur. 34: 769-796.

__________. 1960. Plankton studies of Lake Michigan. II. Thirty-three years of continuous plankton and coliform bacteria data collected from Lake Michigan at Chicago, Illinois. Trans. Amer. Microscop. Soc., 79: 397-404.

__________. 1966. Plankton studies of Lake Michigan. III. Seasonal periodicity of total plankton. Proc. 9th Conf. Great Lakes Res.; Univ. Michigan, Great Lakes Res. Div. Pub. No. 15: 9-17.

DAVIS, C. C. 1966. Plankton studies in the largest Great Lakes of the world, with special reference to the St. Lawrence Great Lakes of North America. Univ. Michigan, Great Lakes Res. Div. Pub. No. 14: 1-36.

EDDY, S. 1927. The plankton of Lake Michigan. Illinois State Nat. Hist. Surv. Bull., 17: 203-232.

GRIFFITH, R. E. 1955. Analysis of phytoplankton yields in relation to certain physical and chemical factors of Lake Michigan. Ecology, 36: 543-552.

LACKEY, J. B. 1944. Quality and quantity of plankton in the south end of Lake Michigan in 1942. J. Amer. Water Works Assn., 36: 669-674.

NALEWAJKO, C. 1966. Dry weight, ash, and volume data for some freshwater planktonic algae. J. Fish. Res. Bd. Canada, 23: 1285-1288.

PANKRATZ, H. S., and C. C. BOWEN. 1963. Cytology of blue-green algae. I. The cells of *Sympleca muscorum*. Amer. J. Bot., 50: 387-399.

SKVORTZOW, B. V. 1937. Diatoms from Lake Michigan. I. Amer. Midland Nat., 18: 652-658.

THOMAS, B. W., and H. H. CHASE. 1887. Diatomaceae of Lake Michigan as collected during the last sixteen years from the water supply of the city of Chicago. Notarisia, 2: 328-330.

WILLIAMS, L. G., and C. SCOTT. 1962. Principal diatoms of the major waterways of the United States. Limnol. Oceanog., 7: 365-379.

# AN HISTORICAL COMPARISON OF OFFSHORE PHYTOPLANKTON POPULATIONS IN LAKE MICHIGAN

E. F. Stoermer

## INTRODUCTION

In attempting to assess the changes in Lake Michigan induced by artificial eutrophication, it is highly desirable to obtain some firm notion of the qualitative changes in the phytoplankton flora over time. The vast majority of studies on Lake Michigan have been concerned primarily with samples taken from inshore localities. Davis (1966) has reviewed the literature pertaining to plankton studies on the Great Lakes. We felt it highly desirable to be able to make comparisons of the qualitative aspects of the offshore flora. The reasons for this are several. Aside from the fact that the offshore plankton undoubtedly constitutes the major portion of the biomass of the lake, this environment is more stable and qualitative changes in the flora are more apt to be truly indicative of long-term environmental changes and less subject to wide fluctuations due to transient conditions.

We felt that the best basis for comparison was Ahlstrom's (1936) study of the deep-water plankton. This investigation, aside from being one of the few that treated the offshore phytoplankton exclusively, best fulfills the criteria of scope, completeness and competence in taxonomy. Ahlstrom's investigation was based on 115 #20 net samples collected during 1930 and 1931. The methodology of the present study was patterned as closely as possible after Ahlstrom in that the same stations were sampled and the same mesh size net was used. The main points of departure were that we had a continuous series of samples from two years rather than early season samples from one part of the lake in one year and a continuous series of samples the next. The total number of samples taken in the present investigation was, thus, somewhat larger (158 vs. 115) than in Ahlstrom's study. The second point was that we used a standard 1/2-meter net rather than the 1-ft open diameter net used by Ahlstrom.

In the following sections, reports of Ahlstrom will be indicated by A and results of the present investigation will be indicated by S with the abundance estimate, in Ahlstrom's categories, immediately following. NR indicates that the species was not recorded.

# RESULTS

## BACILLARIOPHYTA

Ahlstrom categorized the occurrence of the entities he treated in this group under six general headings:

1. Most abundant
2. Species often present in samples but in small numbers
3. Adventitious species abundant in one or several samples
4. Species occurring in five or more samples, usually in small numbers
5. Species noted in one to four samples, always in very limited numbers
6. Species taken in inshore tows at Evanston, Illinois

In reporting the results of the present study, we have followed the same formats Ahlstrom used, to facilitate comparison. We did not repeat his inshore tows at Evanston because of the uncertainty of locating the exact spot sampled and because of the rather large possibility of the physical characteristics of the area being substantially modified during the interval between 1931 and the present. Ahlstrom's reports from these samples are included for reasons that will be apparent later.

### Achnanthes

The majority of the species in this genus grow attached either to solid substrates or to submerged plants. Most freshwater species are in the smaller size range of the group and are thus easily suspended and often appear in the tychoplankton. Some of these small species may also occur attached to some of the larger euplanktonic algae.

*A. affinis* Grun. A-3 S-4

This species is widely distributed in the littoral flora but is considerably less abundant than *A. minutissima* Kütz. Reimer (Patrick and Reimer 1966) has indicated that reports of this entity are to be treated with caution as it is often confused with other species of the genus having similar morphology.

*A. clevei* Grun. A-NR S-2

The fact that Ahlstrom did not report this species is quite surprising in light of our observations. It and its varieties are usually the most common representatives of the genus in the euplankton of hardwater lakes. It is present in low abundance in most plankton collections from Lake Michigan.

*A. clevei* var. *rostrata* Hust. A-NR S-2

Most common representative of the genus in our collections.

| | | |
|---|---|---|
| A. conspicua A. Mayer | A-NR | S-5 |
| A conspicua var. brevistriata Hust. | A-NR | S-4 |
| A. hungarica (Grun.) Grun. | A-NR | S-5 |

This species reaches its greatest abundance in quiet, highly enriched waters. Undoubtedly adventitious in the offshore plankton.

A. lanceolata (Bréb.) Grun. A-NR S-4

One of the most widely distributed members of the genus. It usually occurs attached and is most abundant in small streams and subaerial habitats.

| | | |
|---|---|---|
| A. lanceolata var. omissa Reimer | A-NR | S-5 |
| A. lapidosa Krasske | A-NR | S-5 |
| A. microcephala (Kütz.) Grun. | A-3 | S-5 |

As pointed out under the discussion of A. affinis, reports of the smaller members of the genus should be treated with due caution as several species are practically indistinguishable at the lower limit of their size range. At the present time this species appears to be quite rare in the flora of Lake Michigan, even in its normal habitat in the littoral zone.

A. minutissima Kütz. A-NR S-4

This species also belongs to the "affinis-microcephala" complex of entities that are practically indistinguishable at the lower limits of their size ranges. At the present time this entity is much more common and generally distributed than either A. affinis or A. microcephala.

### Amphipleura Kütz.

A. pellucida (Kütz.) Kütz. A-NR S-3

The distribution of this species in Lake Michigan is somewhat puzzling. It usually grows in the littoral zone in tubular colonies attached to solid substrates or is free living on the bottom. It can, however, under some conditions successfully invade the euplankton. It is often abundant in Green Bay and occasional specimens have been found in collections mady by Thomas from the Chicago City water supply in 1881. Occasional populations are found in the offshore plankton from the southern basin of the lake.

### *Amphiprora* Ehr.

*A. ornata* Bailey A-2 S-2

A large showy species which is apparently a facultative plankter. Reports in the literature tend to over-estimate the abundance of this species because of its relatively large size and ease of recognition.

### *Amphora* Ehr.

Most members of the genus are found in the littoral zone where they grow attached to the coarser algae and to solid substrates. Although no member of the genus which is known to occur in Lake Michigan can be classified as euplanktonic, most of the species are better represented in the plankton than most other members of the littoral community.

*A. ovalis* Kütz. A-5 S-4

*A. ovalis* var. *libyca* (Ehr.) Cleve A-5 S-4

Somewhat more common than the nominate variety in plankton collections.

*A. ovalis* var. *pediculus* Kütz. A-NR S-3

Most common member of the genus in our collections. Its relatively high abundance in the plankton may be explained by the fact that its small size allows it to grow attached to some of the larger euplanktonic diatoms.

### *Anomoeoneis* Pfitzer

*A. vitrea* (Grun.) Ross A-NR S-5

The few specimens noted in our collections come from the northern part of the lake and are undoubtedly derived from the shore flora.

### *Asterionella* Hassall

*A. formosa* Hassall A-1 S-1

Although this species is still one of the major dominants in the offshore plankton, Ahlstrom's remarks would lead us to believe that it is relatively less abundant in our collections than in his.

A-NR S-5

*A*. *gracillima* (Hantz.) Heib.

Although this entity has previously (Eddy 1934) been reported as abundant in Lake Michigan, the circumscription of the taxon is, at present, very tenuous. Entities referable to this species are very rare in our collections and their identification is to be regarded as provisional. The genus is presently under revision.

## *Caloneis* Cleve

A-6 S-NR

*C*. *alpestris* (Grun.) Cleve

A-NR S-5

*C*. *amphisbaena* (Bory) Cleve

This species reaches its highest abundance in quite highly mineralized water. It is common on sandy bottoms in harbors around the lake and is adventitious in the plankton.

A-6 S-5

*C*. *bacillum* (Grun.) Cleve

A very widely distributed species.

A-6 --

*C*. *silicula* (Ehr.) Cleve

Synonym of *C*. *ventricosa* (Ehr.) Meister. For current abundance and distribution see below.

-- S-5

*C*. *ventricosa* (Ehr.) Meister

Very rare in current collections. The few specimens noted have come from the northern portion of the lake.

A-NR S-5

*C*. *ventricosa* var. *minuta* (Grun.) Patr.

Very rare in recent collections.

## *Ceratoneis* Ehr.

A-5 --

*C*. *arcus* (Ehr.) Kütz

This name is a synonym of *Hannaea* *arcus* Patr. For recent distribution of the species, see under that name.

## *Cocconeis* Ehr.

All members of this genus grow attached to submergent plants or to solid substrates. None of the species occurring in Lake Michigan are to be considered euplanktonic, although some of the smaller species may grow attached to the larger planktonic algae.

C. diminuta Pant. A-6 S-4

Widely distributed in our samples but always present in very small numbers.

C. pediculus Ehr. A-6 S-4

Quite common in certain samples especially during the fall months. Usually grows attached to Cladophora spp.and other relatively coarse filamentous algae.

C. placentual Ehr. A-5 S-3

Occasionally present in quantity in fall collections from the southern basin of Lake Michigan. Its growth habit is similar to that of C. pediculus but it seems to thrive on a larger variety of substrates than does that species.

C. placentula var. euglypta (Ehr.) Cleve A-NR S-4

Grows in the same habitats as the nominate variety and in the same or greater abundance. It is, however, less abundant in our plankton samples. It is quite likely that Ahlstrom did not distinguish this variety from the nominate entity.

C. thumensis A. Mayer A-NR S-4

## Coscinodiscus Ehr.

The majority of the members of this genus are confined to the marine environment. Some species invade brackish water and a few are able to exist in fresh water having relatively high TDS levels.

C. asteromorphus Ehr. A-6 S-NR

A marine species whose occurrence in Lake Michigan must be regarded as accidental. Ahlstrom apparently found only one example during his study. Rare examples of similar large marine centric diatoms are found throughout the Great Lakes. They are probably derived from fossil deposits or from diatomaceous earth used in industrial processes.

C. rothii var. subsalsa (Juhl. -Dannf.) Hust. A-NR S-5

Only very few specimens of this entity have been found in the offshore plankton. It does, however, occur in considerable abundance in Muskegon harbor and similar areas. It can be expected to become a more important part of the Lake Michigan flora with continuing pollution as similar species have in Lake Erie.

## *Cyclotella* Kütz.

*C. bodanica* Eulenst. A-1 S-2

As Holland (1965) pointed out, the distinction between this entity and *C. comta* is very tenuous. The apparent reduction in its numbers noted in our study should thus be treated with due caution as it may be generated mostly by differences in interpretation. It has been cited (Hüstedt 1930) as one of the characteristic forms found in oligotrophic alpine lakes.

*C. comta* (Ehr.) Kütz. A-1 S-1

*C. comta* var. *paucipunctata* Grun. A-4 S-4

*C. glomerata* Bach. A-4 S-4

*C. kutzingiana* Thwaites A-4 S-2

*C. kutzingiana* var. *planetophora* Fricke A-NR S-4

*C. kutzingiana* var. *radiosa* Fricke A-NR S-4

*C. melosiroides* (Kirch.) Lemm. A-4 S-5?

We have located only a very few specimens that might be referred to this taxon. Their identification is to be considered tentative.

*C. meneghiniana* Kütz. A-NR S-3

Usually a littoral form but occasionally found in abundance in offshore plankton samples. Reaches its greatest abundance in eutrophic environments.

*C. meneghiniana* fo. *plana* Fricke A-NR S-4

*C. michiganiana* Skv. A-NR S-1

This species is quite similar to *C. striata* (Kütz.) Grun. which is primarily a brackish water form. Its distribution and abundance in Lake Michigan is somewhat unusual. It is the most abundant species in some samples from the southern portion of the lake but is entirely lacking in others. During the years sampled it reached its greatest abundance in September and October, when most other diatoms were at their lowest levels for the year.

*C. ocellata* Pant. A-NR S-2

This species is most common in the northern part of Lake Michigan.

*C. pseudostelligera* Hust. A-NR S-5

This species is quite rare in the offshore plankton but becomes quite abundant in polluted harbors.

*C. stelligera* Cleve and Grun. A-4 S-4

## *Cymatopleura* Wm. Smith

The majority of species in this genus reach their greatest abundance in epipelic communities. Many, however, are found in low abundance in plankton samples. Although they are usually a numerically minor part of the flora, their large size makes them easy to recognize and they tend to be "over-reported."

*C. cochlea* J. Brun A-NR S-4

In contrast to other species of the genus, this entity is more common in the plankton than in epipelic communities. Perhaps only a growth form of *C. elliptica*.

*C. elliptica* (Bréb.) Wm. Smith A-4 S-4

*C. solea* (Bréb.) Wm. Smith A-4 S-4

*C. solea* var. *apiculata* (Wm. Smith) Ralfs A-NR S-4

This entity was more abundant than the nominate variety in our samples.

## *Cymbella* Agardh

Most of the species in this genus reach their maximum abundance in the littoral communities. They may be either free living or occur in colonies of various types. Many of the free living species occur in the tychoplankton in greater or lesser numbers. Often masses of colonial species are also collected in plankton samples from Lake Michigan, especially in the late fall months.

*C. affinis* Kütz. A-NR S-5

*C. angustata* (Wm. Smith) Cleve A-NR S-5

The few specimens noted in our collections come from the northern portion of the lake.

*C. amphicephala* Nägeli A-5 S-5

*C. cistula* (Hempr.) Grun. A-5 S-4

*C. cuspidata* A-5 S-5

*C. cymbiformis* (Kütz.) V. H. A-NR S-5

*C. laevis* Nägeli A-6 S-NR

*C. lanceolata* (Ehr.) V. H. A-5 S-5

*C*. *microcephala* Grun. A-NR S-3

*C*. *naviculaformis* Auerswald A-6 S-NR

*C*. *parva* (Wm. Smith) Cleve A-5 S-NR

*C*. *pusilla* Grun. A-NR S-4

The specimens from Lake Michigan are quite variable. One of the most widely distributed members of the genus in our samples but always present in very low numbers.

*C*. *sinuata* Greg. A-NR S-4

Most specimens come from fall and early spring collections.

*C*. *triangulata* (Ehr.) Cleve A-NR S-4

A relatively large and thick walled species but quite common in the offshore plankton, especially in collections from the northern basin of Lake Michigan. Also abundant in some offshore plankton collections from Lake Superior.

*C*. *ventricosa* Kütz. A-4 S-4

### *Denticula* Kütz.

*D*. *tenuis* var. *crassula* (Nägeli) Hust. A-NR S-4

### *Diatoma* Bory

*D*. *elongata* (Lyngb.) Agardh A-1 --

*D*. *tenue* var. *elongata* var. *elongatum* Lyngb. -- S-1

The two above names are apparent synonyms. For discussion of the nomenclature pertaining to this entity see Patrick (in Patrick and Reimer 1966). Ahlstrom's categories are not fully adequate to describe the abundance and distribution of this taxon. It is present throughout the year in considerable abundance in polluted harbors all around Lake Michigan. In some years it invades the offshore plankton in considerable quantity during the spring warming of the lake. These pulses have been, in our experience, restricted to the southern basin of the lake.

*D*. *tenue* Agardh A-NR S-4

The distribution of this entity is much like that of its variety but it is much less common in the offshore plankton.

*D*. *vulgare* Bory A-5 S-3

Usually grows attached to solid substrates but is a common member of the tychoplankton, especially in the late fall months.

### Diploneis Ehr.

| | | |
|---|---|---|
| D. elliptica (Kütz.) Cleve | A-5 | S-5 |
| D. oculata (Bréb.) Cleve | A-NR | S-5 |
| D. pseudovalis Hust. | A-NR | S-5 |

### Epithemia Kütz.

Members of this genus are most abundant in periphyton communities. They are fairly common in the tychoplankton, but none of the species which occur in Lake Michigan can be classified as euplanktonic.

| | | |
|---|---|---|
| E. argus Kütz. | A-NR | S-5 |

All of our specimens come from the north basin.

| | | |
|---|---|---|
| E. mulleri Fricke | A-6 | S-NR |
| E. turgida (Ehr.) Kütz. | A-6 | S-4 |

### Eucocconeis Cleve

Members of this genus are most abundant in periphyton communities.

| | | |
|---|---|---|
| E. flexella (Kütz.) Hust. | A-6 | S-5 |
| E. lapponica Hust. | A-NR | S-4 |

### Eunotia Ehr.

| | | |
|---|---|---|
| E. tenella | A-NR | S-5 |

Most members of the genus occur only in acid water floras. The few specimens in our collections are undoubtedly allochthonous.

### Fragilaria Lyngb.

Members of this genus occur in both the euplankton and in littoral communities.

| | | |
|---|---|---|
| F. brevistriata Grun. | A-NR | S-3 |
| F. brevistriata var. inflata (Pant.) Hust. | A-NR | S-4 |
| F. capucina Desm. | A-5 | S-3 |

| | | |
|---|---|---|
| *F*. *capucina* var. *mesolepta* Rabh. | A-NR | S-3 |
| *F*. *construens* (Ehr.) Grun. | A-5 | S-4 |
| *F*. *construens* var. *binodis* (Ehr.) Grun. | A-NR | S-5 |
| *F*. *construens* var. *venter* (Ehr.) Grun. | A-NR | S-4 |

All of the above species reach their greatest abundance in eutrophic lakes. In our experience large populations have only been found in samples from the southern basin of Lake Michigan. The "3" designation given several of these species is not actually accurate in that they are euplanktonic species and should not be considered as adventitious. They are apparently not, at present, well established in the Lake Michigan flora as their distribution is irregular.

| | | |
|---|---|---|
| *F*. *crotonensis* Kitton | A-1 | S-1 |

This species is one of the major dominants in the Lake Michigan flora. The populations from Lake Michigan are extremely variable in morphology and further study may show that more than one taxon has been included under this designation. Present evidence in the literature indicates that this species is tolerant of a wide range of ecologic conditions.

| | | |
|---|---|---|
| *F*. *harrisonii* (Wm. Smith) Grun. | A-4 | -- |
| *F*. *harrisonii* var. *dubia* Grun. | A-4 | -- |
| *F*. *harrisonii* var. *rhomboides* Grun. | A-6 | -- |

The above entities are synonyms of *F*. *leptostauron* et var. For recent abundance and distribution see under that taxon.

| | | |
|---|---|---|
| *F*. *intermedia* Grun. | A-NR | S-3 |
| *F*. *leptostauron* (Ehr.) Hust. | -- | S-4 |
| *F*. *leptostauron* var. *dubia* (Grun.) Hust. | -- | S-4 |
| *F*. *pinnata* Ehr. | A-NR | S-3 |
| *F*. *virescens* Ralfs | A-1 | S-NR |

We regard this identification of Ahlstrom's as a dubious record. It is quite likely that this taxon was confused with *F*. *capucina* et var.

### *Gomphonema* Agardh

Species of this genus are most common in periphyton communities. Most species usually grow attached in dendritic colonies to solid substrates but can also exist as single free living cells.

| | | |
|---|---|---|
| *G. acuminatum* var. *coronata* (Ehr.) Wm. Smith | A-5 | S-5 |
| *G. angustatum* (Kütz.) Rabh. | A-NR | S-3 |
| *G. constrictum* var. *capitata* (Ehr.) Cleve | A-NR | S-5 |
| *G. intricatum* Kütz. | A-5 | S-5 |
| *G. intricatum* var. *pumila* Grun. | A-NR | S-4 |
| *G. montanum* Schum. | A-3 | S-NR |
| *G. olivaceum* (Lyngb.) Kütz. | A-6 | S-4 |
| *G. olivaceum* var. *calcarea* Cleve | A-6 | S-5 |
| *G. parvulum* (Kütz.) Kütz. | A-3 | S-4 |
| *G. parvulum* var. *micropus* (Kütz.) Cleve | A-NR | S-5 |
| *G. turris* Ehr. | A-NR | S-5 |

### *Gyrosigma* Hassall

| | | |
|---|---|---|
| *G. acuminatum* (Kütz.) Rabh. | A-6 | S-5 |
| *G. attenuatum* (Kütz.) Rabh. | A-NR | S-5 |

### *Hannaea* Patr.

| | | |
|---|---|---|
| *Hannaea arcus* (Ehr.) Patr. | -- | S-5 |

### *Melosira* Agardh

Members of this genus are common and often dominant in freshwater plankton communities. Most species are polymorphic and notoriously difficult to reliably identify.

| | | |
|---|---|---|
| *M. binderana* Kütz. | A-NR | S-3 |

The "3" designation for this species is somewhat misleading in that it is euplanktonic and will undoubtedly become established in the offshore plankton of Lake Michigan with increasing eutrophication. At present it is established in polluted harbors all around the lake. Previous to this year (1967) we had found only isolated populations in the offshore plankton. This spring it was present in quantity over the entire southern basin of the lake.

*M. crenulata* (Ehr.) Kütz. A-4 --

Apparent synonym of *M. italica* (Ehr.) Kütz. For recent distribution of the species see under that name.

*M. distans* (Ehr.) Kütz. A-4 S-5

*M. granulata* (Ehr.) Ralfs A-4 S-3

This species is abundant in harbors and in some inshore waters. At present occasional populations are found in the offshore plankton. It is euplanktonic and can be expected to become more abundant in the offshore waters.

*M. granulata* var. *angustissima* O. Müll. A-NR S-3

Has about the same apparent ecologic valence as the nominate variety.

*M. islandica* O. Müll. A-1 S-1

Ahlstrom reported this entity as *M. islandica* subsp. *helvetica* O. Müll. In our material no distinction can be made between the nominate variety and the supposed subspecies. The morphology of the valve is quite variable, but the differences in wall thickness grade into one another in a continuous series. One of the major dominants in the Lake Michigan flora.

*M. italica* (Ehr.) Kütz. -- S-3

Although the species is apparently euplanktonic, only isolated populations have been found in the offshore plankton.

*M. italica* var. *tenuissima* (Grun.) O. Müll. A-NR S-5

M. *varians* Agardh A-5 S-4

## *Meridion* Agardh

*M. circulare* var. *constrictum* (Ralfs) V. H. A-NR S-5

## *Navicula* Bory

Largest and most widely distributed of the diatom genera. None of the species occurring in Lake Michigan can be considered euplanktonic in the strict sense of the term. Many species are abundant in the tychoplankton and some of these are routinely found, in limited numbers, in offshore plankton collections.

Although the number of species occurring in our samples is relatively great, their numerical contribution to the total flora is relatively small.

| | | |
|---|---|---|
| *N. anglica* Ralfs | A-5 | S-4 |
| *N. bacillum* Ehr. | A-6 | S-NR |
| *N. capitata* Ehr. | A-NR | S-5 |
| *N. cryptocephala* Kütz. | A-6 | S-4 |
| *N. cryptocephala* var. *veneta* (Kütz.) Rabh. | A-NR | S-4 |
| *N. cuspidata* (Kütz.) Kütz. | A-6 | S-5 |
| *N. decussis* Ostr. | A-NR | S-4 |
| *N. exigua* Greg. ex Grun. | A-6 | S-NR |
| *N. gastrum* Ehr. | A-6 | S-5 |
| *N. gastrum* var. *signata* Hust. | A-NR | S-5 |
| *N. integra* (Wm. Smith) Ralfs | A-NR | S-5 |
| *N. lanceolata* (Agardh) Kütz. | A-NR | S-4 |
| *N. menisculus* var. *upsalensis* (Grun.) Grun. | A-NR | S-5 |
| *N. minima* Grun. | A-NR | S-3 |
| *N. mutica* Kütz. | A-NR | S-5 |
| *N. oblonga* Kütz). | A-6 | S-NR |
| *N. oblonga* var. *subcapitata* Pant. | A-6 | S-NR |
| *N. odiosa* Wallace | A-NR | S-5 |
| *N. platystoma* Ehr. | A-6 | S-4 |
| *N. platystoma* var. *pantocsekii* Wisl. and Kolbe | A-NR | S-4 |
| *N. protracta* Grun. | A-6 | S-5 |
| *N. radiosa* Kütz. | A-5 | S-2 |
| *N. radiosa* var. *tenella* (Kütz.) Grun.<br>Most common member of the genus in our collections. | A-NR | S-2 |

| | | |
|---|---|---|
| *N.* *reinhardtii* Grun. | A-6 | S-4 |
| *N.* *seminulum* Grun. | A-NR | S-5 |
| *N.* *tripunctata* (Mill.) Bory | A-NR | S-4 |
| *N.* *tuscula* (Ehr.) Grun. | A-5 | S-5 |
| *N.* *viridula* (Grun.) V. H. | A-6 | S-5 |
| *N.* *viridula* var. *linearis* Hust. | A-NR | S-5 |

## *Neidium* Pfitzer

| | | |
|---|---|---|
| *N.* *dubium* (Ehr.) Cleve | A-NR | S-4 |
| N. *iridis* (Ehr.) Cleve | A-6 | S-5 |

## *Nitzschia* Hassall

Although the majority of species in the genus grow either free living or attached in littoral communities, they occur regularly in the tychoplankton and several species are euplanktonic. The fact that some species in the genus occur in great abundance in very strongly eutrophied waters has led some authors to consider abundance of the genus to be an indicator of eutrophy. Although this view is an over-generalization as some species are confined to oligotrophic and dystrophic habitats, it finds some support in the general case.

| | | |
|---|---|---|
| N. *acuta* Hantz. | A-NR | S-5 |
| N. *amphibia* Grun. | A-5 | S-4 |
| N. *angustata* (Wm. Smith) Grun. | A-NR | S-2 |
| *N.* *angustata* var. *acuta* Grun. | A-NR | S-5 |

The above two entities are present in most of our samples from the southern basin of the lake in low abundance. Their taxonomic separation is questionable.

| | | |
|---|---|---|
| N. *baccata* Hust.? | A-NR | S-4 |
| N. *confinis* Hust.? | A-NR | S-4 |

The above two entities have previously been reported as euplanktonts in tropical areas.

| | | |
|---|---|---|
| *N. dissipata* (Kütz.) Grun. | A-NR | S-2 |
| *N. fonticola* Grun. | A-NR | S-3 |
| *N. fonticola* var. *pelagica* Hust. | A-NR | S-4 |
| *N. frustulum* var. *perminuta* Grun. | A-NR | S-4 |
| *N. holsatica* Hust. | A-NR | S-3 |

This species is apparently euplanktonic. At present it established in harbors and some inshore areas in the southern basin of the lake. Occasional outbursts are noted in offshore plankton collections from the southern basin. According to Hustedt (1930) the species is usually associated with blue-green algal blooms.

| | | |
|---|---|---|
| *N. lauenburgania* Hust. | A-NR | S-4 |
| *N. linearis* Wm. Smith | A-5 | S-5 |
| *N. palea* (Kütz.) Wm. Smith | A-5 | S-5 |
| *N. recta* Hantz. | A-NR | S-2 |
| *N. sigmoidea* (Ehr.) Wm. Smith | A-4 | S-4 |
| *N. vermicularis* (Kütz.) Grun. | A-NR | S-5 |

### *Pinnularia* Ehr.

| | | |
|---|---|---|
| *P. major* (Ehr.) Cleve | A-6 | S-NR |

### *Rhizosolenia* Ehr.

All members of the genus are euplanktonic. The great majority of species are marine but several, including those reported below, are restricted to freshwater.

| | | |
|---|---|---|
| *R. eriense* H. L. Smith | A-1 | S-1 |
| *R. gracilis* H. L. Smith | A-2 | S-2 |

### *Rhoicosphenia* Grun.

| | | |
|---|---|---|
| *R. curvata* (Kütz.) Grun. | A-NR | S-3 |

Generally grows attached to filamentous algae or aquatic plants in the littoral zone. Quite abundant in a few fall samples.

### *Rhopalodia* O. Müll.

*R. gibba* (Ehr.) O. Müll. A-NR S-5
Usually attached to aquatic plants or to solid substrates.

### *Stauroneis* Ehr.

*S. anceps* Ehr. A-6 S-NR

*S. phoenicenteron* Ehr. A-NR S-5

### *Stephanodiscus* Ehr.

All species of this genus recorded from Lake Michigan are euplanktonic. The taxonomy of the genus is, at present, extremely confused and many of the older distribution records from the lake are open to serious question.

*S. alpinus* Hust. A-NR S-2

*S. astraea* (Ehr.) Grun. A-1 S-4
In our experience large populations of this species are found only in inshore and harbor floras. Occasional specimens are found in the offshore plankton but they always constitute a minor part of the flora.

*S. astraea* var. *minutula* (Kütz.) Grun. A-2 S-2

*S. hantzschii* Grun. A-NR S-3
An apparent recent introduction to the Lake Michigan flora (Skvortzow 1937). This organism forms nusiance "blooms" in harbors and some inshore waters but, at present, only isolated populations are found in the southern basin of the lake. It can be expected to become an important part of the offshore flora in the future.

*S. niagarae* Ehr. A-- S-2
Ahlstrom considered this to be a doubtful species and probably a synonym of *S. astraea*. We have found it to be common in collections from all areas of the lake, expecially in the fall, but usually present in rather low numbers.

*S. niagarae* var. *magnifica* Fricke A-NR S-4

*S. tenuis* Hust. A-NR S-5

*S. transilvanicus* Pant. A-NR S-2
This species has apparently been considered as part of *S. astraea* by most authors. It is present in samples dating back to 1881.

## *Surirella* Turp.

| | | |
|---|---|---|
| *S. angustata* Kütz. | A-4 | S-4 |
| *S. biseriata* var. *bifrons* (Ehr.) Hust. | A-6 | S-5 |
| *S. didyma* Kütz. | A-6 | S-NR |
| *S. ovata* Kütz. | A-4 | S-3 |
| *S. ovata* var. *crumena* (Bréb.) V. H. | A-NR | S-5 |

## *Synedra* Ehr.

| | | |
|---|---|---|
| *S. acus*. Kütz.<br>Abundant in spring collections from the southern basin of Lake Michigan. | A-4 | S-3 |
| *S. delicatissima* var. *angustissima* Grun. | A-NR | S-4 |
| *S. fasciculata* (Agardh) Kütz. | A-NR | S-3 |
| *S. parasitica* (Wm. Smith) Hust. | A-6 | S-4 |
| *S. radians* Kütz. | A-1 | S-2 |
| *S. ulna* (Nitzsch) Ehr.<br>Ahlstrom apparently did not separate the varieties of this species. The nominate variety usually grows attached and, in our experience, is rather rare in the euplankton. Some of the varieties (below) are adapted to existance in the plankton and are much more common in our samples. | A-1 | S-4 |
| *S. ulna* var. *chaseana* Thomas<br>One of the major dominants in fall collections. | A-NR | S-1 |
| *S. ulna* var. *danica* (Kütz.) V. H. | A-NR | S-2 |
| *S. ulna* var. *longissima* (Wm. Smith) Brun.<br>Occasional populations in the offshore plankton, expecially from the northern basin of the lake. | A-NR | S-4 |
| *S. ulna* var. *subaequalis* (Grun.) V. H. | A-NR | S-5 |
| *S. vaucheriae* Kütz. | A-3 | S-3 |

### *Tabellaria* Ehr.

Members of this genus are the overwhelming dominants in the Lake Michigan plankton in nearly all collections. The specific taxonomy is, at present, in a state of almost total confusion. Populations from the Great Lakes are highly variable and specific records are to be treated with caution.

*T. fenestrata* (Lyngb.) Kütz. A-1 S-1

*T. fenestrata* var. *geniculata* A. Cleve A-NR S-4
Most common in collections from the northern basin of the lake.

*T. flocculosa* (Roth) Kütz. A-1 S-1

*T. quadriseptata* Knudson ? A-NR S-4
The circumscription of this taxon is extremely tenuous. Some specimens in our collections agree with Knudson's (1952) description.

### *Thalassiosira* Cleve

*T. fluviatilis* Hust. A-NR S-5

*T. levanderi* Van Goor A-NR S-5
The majority of species in this genus are marine. The two recorded here occur in brackish water and freshwater of high conductivity. They are both very rare in collections from the southern basin of the lake.

## CHLOROPHYTA

Compared to the diatoms, this group comprises a very minor fraction of the total offshore net plankton. For this reason Ahlstrom reported his observations in a somewhat different format. We will follow the same method of reporting as outlined below. It should be emphasized that the "abundant" species are abundant only in the sense of their almost universal occurrence rather than in the sense of contributing a significant portion of the total number of plankton organisms.

1. The more abundant species
2. Species noted in ten or more samples as rare forms
3. Species noted in one or a very few samples in small numbers
4. Species noted by the author in inshore tows at Evanston, Illinois

As we pointed out before, the inshore tows at Evanston were not repeated in the present study.

### *Ankistrodesmus* Corda

*A. falcatus* (Corda) Ralfs A-2 S-2

Most common in fall collections in our experience. Populations from Lake Michigan are quite variable. Some of our specimens approach the morphology of *A. falcatus* var. *acicularis* (Braun) G. S. West.

### *Botryococcus* Kütz.

*B. braunii* Kütz. A-2 S-1

Mature colonies of this species float on the surface of the water. It is present in the majority of our collections and is quite abundant in some fall collections.

### *Coelastrum* Nägeli

*C. microsporum* Nägeli A-2 S-2

*C. reticulatum* (Dang.) Senn A-3 S-2

### *Closterium* Nitz.

*C. acirculare* West A-1 S-1

This species is almost universally present in our samples but always in relatively low abundance.

### *Cosmarium* Corda

*C. contractum* Kirch. A-3 S-3

*C. depressum* var. achondrum (Bolt) West A-1 S-3?

### *Crucigenia* Morren

*C. quadrata* Morren A-2 S-2

### *Dictyosphaerium* Nägeli

*D. ehrenbergianum* Nägeli A-3 S-2

| | | |
|---|---|---|
| *D. pulchellum* Wood | A-1 | S-1 |

This species is one of the most common members of the group in our collections.

### *Dimorphococcus* Braun

| | | |
|---|---|---|
| *D. lunatus* A. Braun | A-3 | S-3 |

### *Elakatothrix* Wille

| | | |
|---|---|---|
| *E. gelatinosa* Wille | A-NR | S-3 |
| *E. viridis* (Snow) Printz? | A-NR | S-3 |

### *Eudorina* Ehr.

| | | |
|---|---|---|
| *E. elegans* Ehr. | A-3 | S-NR |

### *Franceia* Lemm.

| | | |
|---|---|---|
| *F. droescheri* (Lemm.) G. M. Smith | A-NR | S-2 |

### *Glaucocystis* Itzigsohn

| | | |
|---|---|---|
| *G. oocystiformis* Prescott ? | A-NR | S-3 |

### *Gloeocystis* Nägeli

| | | |
|---|---|---|
| *G. gigas* (Kütz.) Lagerh. | A-3 | S-3 |

### *Golenkinia* Chodat

| | | |
|---|---|---|
| *G. radiata* (Chod.) Wille | A-NR | S-3 |

### *Kirchneriella* Schmidle

| | | |
|---|---|---|
| K. *lunaris* (Kirch.) Möb. | A-3 | S-2 |
| K. *obesa* (West) Schmidle | A-3 | S-3 |

### *Lagerheimia* (De Toni) Chodat

| | | |
|---|---|---|
| *L. longiseta* (Lemm.) Printz | A-3 | S-3 |

### *Micractinium* Fres.

| | | |
|---|---|---|
| *M. pusillum* Fres. | A-4 | S-3 |
| *M. quadrisetum* (Lemm.) G. M. Smith | A-4 | A-NR |

### *Nephrocytium* Nägeli

| | | |
|---|---|---|
| *N. agardhianum* Nägeli | A-2 | S-2 |
| *N. limneticum* (G. M. Smith) G. M. Smith? | A-3 | S-3 |

### *Oocystis* Nägeli

| | | |
|---|---|---|
| *O. borgei* Snow | A-4 | S-NR |
| *O. crassa* Wittrock | A-4 | S-NR |
| *O. elliptica* var. *minor* West | A-NR | S-1 |
| *O. lacustris* Chodat | A-2 | S-2 |
| *O. submarina* Lagerh. | A-2 | S-2 |

Members of this genus are present in most samples and become quite abundant in some fall collections. Peak populations of members of this genus (and the green algae in general) occur at the time of minimum diatom populations.

### *Pediastrum* Meyen

| | | |
|---|---|---|
| *P. boryanum* (Turp.) Menegh. | A-2 | S-3 |
| *P. boryanum* var. *longicorne* Raciborski | A-3 | S-2 |
| P. *duplex* Meyen | A-2 | S-2 |
| *P. simplex* (Meyen) Lemm. | A-3 | S-3 |
| *P. simplex* var. *duodenarium* (Bailey) Rabh. | A-3 | S-2 |

Members of this genus are abundant in collections from harbors and eutrophied inshore waters around the lake. Populations are very scattered in the offshore plankton. They are very rare in the northern basin of the lake but are increasingly common in the southern basin.

### *Quadrigula* Printz

| | | |
|---|---|---|
| *Q. chodatii* (Tan.-Ful.) G. M. Smith | A-NR | S-3 |

### *Scenedesmus* Meyen

| | | |
|---|---|---|
| *S. abundans* (Kirch.) Chodat | A-3 | S-3 |
| *S. arcuatus* Lemm. | A-4 | S-NR |
| *S. armatus* (Chod.) G. M. Smith | A-3 | S-3 |
| *S. dimorphus* (Turp.) Kütz. | A-3 | S-3 |
| *S. ecornis* (Ralfs) Chodat | A-3 | S-NR |
| *S. platydisca* (G. M. Smith) Chodat | A-4 | S-NR |
| *S. quadricauda* (Turp.) Bréb. | A-3 | S-3 |

Most of our populations come from the southern basin of Lake Michigan. Populations are very scattered but occasional samples contain an abundance of members of the genus, especially *S. quadricauda*, which is generally abundant in harbors and some inshore waters.

### *Selenastrum* Reinsch

| | | |
|---|---|---|
| *S. bibraianum* Reinsch | A-3 | S-NR |
| *S. westii* G. M. Smith | A-NR | S-3 |

### *Sphaerocystis* Chodat

| | | |
|---|---|---|
| *S. schroeteri* Chodat | A-1 | S-1 |

Very common in our collections.

### *Staurastrum* Meyen

| | | |
|---|---|---|
| *S. contortum* G. M. Smith | A-3 | S-NR |
| *S. cuspidiatum* Bréb. | A-3 | S-3 |
| *S. longiradiatum* West | A-3 | S-NR |

### *Tetraëdron* Kütz.

| | | |
|---|---|---|
| T. *minimum* (Braun) Hansg. | A-NR | S-2 |

## CHRYSOPHYTA

Ahlstrom treated most of the members of this group that occur in the euplankton as protozoa. He did not devise a numerical classification for abundance as he did for other groups, but chose to discuss the abundance of each entity separately. In the following compilation we will summarize his remarks.

### *Dinobryon* Ehr.

Members of this genus are one of the major components of the Lake Michigan flora. In our experience the populations of the various species are very scattered and samples from adjacent stations will often show strikingly different abundance and species composition.

*D. bavaricum* Imhof

Ahlstrom noted that this species was present in a number of collections but abundant in only a few. It was very rare in our samples.

*D. cylindricum* Imhof

Ahlstrom recorded this species as being abundant in collections from May to August. It was the second most abundant species of the genus in our samples.

*D. divergens Imhof*

Ahlstrom recorded this as the most abundant member of the genus in his collections, which agrees with our results.

*D. sertularia* var. *protruberans* (Lemm.) Krieger ?

Poorly distinguished from the nominate variety. Ahlstrom recorded this entity as being abundant in fall collections. It was quite rare in our material although a few populations were found in fall collections from the northern basin.

D. sociale Ehr.

Ahlstrom recorded this species as being present in most collections and dominant in some. Populations in our samples were extremely variable. It was entirely missing from many samples but was the dominant organism in others. It was especially abundant in some spring collections from the southern basin.

### Mallomonas Perty

M. alpina Pascher

Ahlstrom recorded this species as present in several samples. It was very rare in our material and its identification is questionable.

M. caudata Iwanoff

Not recorded by Ahlstrom, this species was present in many of our samples but always in very low numbers.

M. producta (Zach.) Iwanoff

Ahlstrom recorded this species as present in low numbers in most collections, which agrees with our observations.

### Synura Ehr.

S. uvella Ehr.

Ahlstrom reported that this species became very abundant in July and August of 1931 and "came as near forming a 'wave' as any species noted in the plankton." No such bloom was noted in our collections. During our study isolated populations were noted in some samples but the organism never became a dominant member of the plankton community. Contrary to Ahlstrom's observations, the highest populations we noted occurred in the spring samples rather than in the fall.

### Uroglenopsis Lemm.

Ahlstrom recorded this species as being very rare. This agrees with our observations. It was recorded from only two samples and then in very low abundance during our study.

## CYANOPHYTA

The nomenclature of this group is presently in a state of flux. Since Ahlstrom's study was published, the coccoid genera have been revised (Drouet and Dailey 1956) and the genera belonging to the Oscillatoriales are under revision. The very substantial changes in nomenclature put forth in these revisions reflect both strict adherence to the rules of botanical nomenclature and a very real difference in interpretation of structure and structural variation from that put forth in previous treatments. All of this makes comparison of results very tenuous without reference to original specimens. For purposes of comparison we have attempted to categorize our specimens according to the same systematic reference works and nomenclature used by Ahlstrom. While this expedient undoubtedly introduces some ambiguities we feel that it allows more confidence in the comparisons made than an attempt to interpret Ahlstrom's determinations on the basis of a different philosophical and nomenclatural treatment.

Contrary to some previously published reports, we found the blue-green algae to be a very minor constituent of the Lake Michigan flora, at least in the offshore waters.

Ahlstrom categorized this group under three classes of abundance as follows: (1) the more common species, (2) species occurring in five or more samples in small numbers, (3) species occurring in less than five samples as rare forms.

As with the previous groups, we will follow his format for purposes of comparison.

### *Anabaena* Bory

| | | |
|---|---|---|
| *A. flos-aquae* (Lyngb.) Bréb. | A-3 | S-2 |
| *A. lemmermannii* Richter | A-1 | S-- |

Most authors treat the above two epithets as synonyms. We could find no basis for the separation made by Ahlstrom and have reported all of our specimens of the genus under the former name.

### *Aphanocapsa* Nägeli

| | | |
|---|---|---|
| *A. elachista* var. *conferta* West and West | A-2 | S-2? |

### *Aphanothece* Nägeli

| | | |
|---|---|---|
| *A. nidulans* Richter | A-2 | S-2 |

### *Chroococcus* Nägeli

| | | |
|---|---|---|
| C. *limneticus* Lemm. | A-1 | S-1 |

| | | |
|---|---|---|
| *C. minutus* (Kütz.) Nägeli | A-3 | S-1 |
| *C. turgidus* (Kütz.) Nägeli | A-3 | S-2 |
| *Coelosphaerium* Nägeli | | |
| *C. kuetzingianum* Nägeli | A-2 | S-2? |
| *C. naegelianum* Unger | A-1 | S-1 |
| *Dactylococcopsis* Hansgrig | | |
| *D. fascicularis* Lemm. | A-NR | S-2 |
| *Gomphosphaeria* Kütz. | | |
| *G. lacustris* Chodat | A-1 | S-1 |
| *Lyngbya* Agardh | | |
| *L. lagerheimii* (Möb.) Gom. | A-3 | S-3 |
| *L. contorta* Lemm. | A-NR | S-3 |
| *Merismopedia* Meyen | | |
| *M. glauca* (Ehr.) Kütz. | A-2 | S-2 |
| *Microcystis* Kütz. | | |
| *M. aeruginosa* Kütz. | A-3 | S-2? |
| *M. flos-aquae* (Wittr.) Kirch. | A-1 | S-2? |
| *M. pulvera* var. *incerta* (Lemm.) Crow | A-3 | S-2 |
| *Oscillatoria* Vaucher | | |
| *O. mougeotii* Kütz. | A-1 | S-1? |

### Spirulina Turpin

S. laxissima West A-NR S-2

## PYRROPHYTA

In Ahlstrom's report the dinoflagellates are treated as protozoa. The identifications of entities in this group were apparently done by G. H. Wailes rather than by Ahlstrom himself. As is the case with the other various taxonomic groups he included under the protozoa, distribution and abundance are discussed separately rather than according to a numerical classification as in the major algal phyla. In our samples the occurrence of the species noted was extremely irregular, both seasonally and in terms of sampling area.

### Ceratium Schrank

C. hirundinella (O. F. M.) Schrank

Ahlstrom noted that this species was present in most collections taken throughout the year but did not become abundant until July in both years' samples. This essentially agrees with our observations although we did find an apparent localized bloom in one sample from off Waukegon, Ill., in June.

### Peridinium Ehr.

Ahlstrom lists the following species of this genus as occurring in his samples:

P. geminum var. contracta Lind.

P. minusculum Lind.

P. minusculum var. spinifera Lind.

P. tabulatum Ehr.

P. volzi Lemm.

P. wisconsinense Eddy

According to him all of the above entities are "of rare or solitary occurrence" except P. tabulatum which was "present in a number of samples." Only two species were noted in our collections. The first of these is widely distributed in our samples but never abundant. Although its taxonomic affinities are uncertain, it is probably the same entity that Ahlstrom recorded as P. tabulatum with reservations. P. wisconsinense was also present in 4 of our samples in very low abundance.

## DISCUSSION AND CONCLUSIONS

The salient points of difference shown by this comparative study are the increasing abundance of entities that have their primary habitat in the littoral zone in the euplankton and the apparent introduction of several new euplanktonic species into the Lake Michigan flora.

The causes for the first phenomenon are not clear-cut. Undoubtedly some of the differences noted are accidental. Even with exhaustive analysis some entities remain undetected in phytoplankton samples. Some of the widely distributed species in the Lake Michigan plankton have a normal frequency of occurrence of one specimen per $10^5$ total cells in net plankton samples. The weight of evidence, however, points to the conclusion that this apparent rise in the number of adventitious species occurring in the offshore net plankton is real and is attributable to increased eutrophication of the habitat. It should first be pointed out that the offshore plankton community of the Great Lakes is a highly specialized habitat that cannot be strictly compared either to the euplankton of the seas or to the plankton of smaller lakes. Due to their, geologically speaking, transient nature the Great Lakes have not developed the rich euplanktonic species pool found in the open ocean. Due to the rigidity of the environment the trychoplanktonic species which make up the majority of species occurring (although not numbers of individuals) in smaller bodies of fresh water are effectively excluded. The "natural" euplanktonic flora of the Great Lakes is thus strikingly depauperate in forms and seasonally stable when compared to other plankton habitats. Increasing eutrophy would logically tend to modify this condition in two ways so far as the adventitious species are concerned. With higher nutrient levels the algal biomass of the littoral zone will doubtlessly increase, furnishing a greater source of inoculum to the offshore waters. The same increased nutrient levels also tend to allow whatever adventitious species are derived from the littoral zone to survive for longer periods of time in the plankton. This tendency is, at present, most strikingly illustrated in the southern basin of the lake where detached masses of periphyton algae large enough to be visible to the naked eye are often taken in offshore net hauls. It should be pointed out that our estimates of the relative abundance of tychoplanktonic species are very conservative in that the reports from inshore tows at Evanston have been included in the Ahlstrom totals. If these records were excluded, as they have been in our investigation, the apparent difference would be yet greater.

Of the 35 euplanktonic taxa noted in this study which were not reported by Ahlstrom, over 70% are reported in the literature as occurring primarily in eutrophic habitats. The majority of these entities have been, until very recently, quite rare in the offshore plankton although almost universally present and abundant in harbors and some inshore waters of Lake Michigan. Although such estimates of ecologic valence are qualitative and subject to considerable argument in the literature, we feel that our estimate is very conservative. It would be quite interesting to develop similar estimates for the tychoplanktonic entities, but this proves to be beyond the scope of the present investigation.

## SUMMARY

| | Ahlstrom 1936 | Stoermer Present |
|---|---|---|
| Total taxa | 160 | 247 |
| Euplanktonic | 96 (60% of total) | 131 (53% of total) |
| Tychoplanktonic | 64 (40% of total) | 116 (47% of total) |

| | % Increase | % Eutrophic Species |
|---|---|---|
| Total increase 87 taxa | 64% | ? (insufficient evidence) |
| Euplanktonic 35 | 40% | 71% |
| Tychoplanktonic 52 | 60% | ? (insufficient evidence) |

## REFERENCES

AHLSTROM, E. H. 1936. The deep-water plankton of Lake Michigan, exclusive of the Crustacea. Trans. Am. Microscop. Soc., 55: 286-299.

DAVIS, C. C. 1966. Plankton studies in the largest Great Lakes of the world, with special reference to the St. Lawrence Great Lakes of North America. Univ. Michigan, Great Lakes Res. Div. Pub. 14: 1-36.

DROUET, F., and W. A. Daily. 1956. Revision of the Coccoid Myxophyceae. Butler Univ. Bot. Stud., 12: 1-218.

EDDY, S. 1934. A study of fresh-water plankton communities. Illinois Biol. Monogr., 12: 1-93.

HOLLAND, R. E. 1965. The distribution and abundance of planktonic diatoms in Lake Superior. Proc. 8th Conf. Great Lakes Res.; Univ. Michigan, Great Lakes Res. Div. Pub. 13: 96-105.

HUSTEDT, F. 1930. Bacillariophyta (Diatomeae). *In* A. Pascher (ed.), Die Süsswasser-Flora Mitteleuropas, Heft 10. Gustav Fischer Verlag, Jena. 466 p.

KNUDSON, B. M. 1952. The diatom genus *Tabellaria*. I. Taxonomy and morphology. Annals Bot. N. s. 16(63): 421-440.

PATRICK, R., and C. W. Reimer. 1966. The diatoms of the United States, exclusive of Alaska and Hawaii. Vol. Acad. Nat. Sci. Philadelphia Monogr. 13. Livingston Pub. Co., Philadelphia. 688 p.

SKVORTZOW, B. V. 1937. Diatoms from Lake Michigan. I. Am. Midland Nat. 18: 652-658.

# ZONATION OF THE BENTHIC ENVIRONMENT IN LAKE MICHIGAN

Charles F. Powers and Andrew Robertson

## INTRODUCTION

Studies of the benthic environment in the upper Great Lakes have increased markedly over the past decade. Whereas the only thorough study of the macrobenthos in the upper lakes prior to World War II was that of Eggleton (1936, 1937) in Lake Michigan, since that time, and especially since 1960, a number of workers have investigated various aspects of the macrobenthos. For Lake Michigan, Merna (1960) presented data relating to the geographic and topographic distribution of numbers of benthic organisms; Cook and Powers (1964) made an intensive study of the macrobenthos in the immediate vicinity of the St. Joseph River and attempted to relate the effect of the river outflow to the distribution of the organisms; Powers and Robertson (1965) investigated the areal and depth distribution of the macrobenthos in the southern two-thirds of the lake with respect to both numbers and kinds of organisms and ash-free dry weight; and Robertson and Alley (1966) made a study comparing the quantity of macrobenthos in the lake in 1964 with that found by Eggleton in the early 1930's. For Lake Huron, Teter (1960) presented data on the numbers and kinds of macrobenthic organisms and their relation to depth; Henson and Herrington (1965) carried out a taxonomic and distributional study of the sphaeriids in the Straits of Mackinac region; and Schuytema and Powers (1966) studied the distribution of numbers of organisms in the lake and compared this with investigations they had made in Lake Michigan.

It is obvious, then, that there is increasing interest in the benthic communities of the upper Great Lakes. Long-term studies of the macrobenthos of Lake Michigan were initiated by the Great Lakes Research Division in 1964, and are still going on. It has become increasingly obvious that benthic productivity is influenced by a complex of certain environmental factors, and we have directed considerable attention to some aspects of the environment which might be expected to influence the occurrence of bottom-associated organisms. Emphasis to date has been upon the identification of sediment types; their distribution from the standpoints of depth, bottom topography, and geographical location; and the quantity of organic matter which they contain. This paper presents the results of our investigations upon the benthic environment and outlines the interrelationships among sediment type, organic carbon, and water depth which have become apparent. This work has permitted the definition of rather discrete benthic zones whose biological significance will be treated in a forthcoming paper.

We are very glad to be able to acknowledge the work of Mrs. Jeanne Rose and Mr. David Bos who performed the organic carbon analyses, and to extend our thanks to Mr. Paul Josephson for permission to utilize his unpublished data on sediment analyses. Many other members of the Division staff contributed to this work through their participation in the field work, and to all these we extend our sincere thanks.

In addition to its appearance in this report, this paper is being submitted for publication in a technical journal.

## METHODS

The benthic environment of Lake Michigan has been sampled monthly over the past several years, except for the winter months, at 34 stations located in the southern two-thirds of the lake (dark circles, Fig. 1). These stations were sampled on an average of 15 times from August 1964 through June 1966. Triplicate grab samples of the bottom sediments were obtained during each station visit for studies on the macrobenthos (Powers and Robertson 1965) and for identification of sediment type. Additional samples for the determination of the organic carbon content of the sediments were obtained at these stations in July and October 1965 and April 1966.

Samples were taken with the Smith-McIntyre dredge (McIntyre 1954) until June 1965, and the Ponar grab sampler (Powers and Robertson 1967) therafter. Visual descriptions of the sediment were made routinely on the freshly taken bottom samples. The grab was opened into a large washtub and the sediment carefully transferred to the tub in an undisturbed condition. The composition of the sample was estimated with respect to apparent sand, silt, and clay content; inclusions such as granules, pebbles, and cinders were noted; and all visible layers were described individually. This resulted in such descriptions as "clean medium sand," "fine silty sand," "dark slightly sandy silt over tan plastic clay," and the like. Sediment color was also estimated and recorded.

An inspection of the bathymetry of the lake (Fig. 2) shows a definite tendency for a division into two basins, separated by a partial sill extending roughly between Muskegon on the east side to Milwaukee-Port Washington on the west. This sill is its shallowest in mid-lake where it shoals to about 44 m (24 fm). The sill does not extend continuously to either shore, being interrupted by relatively deep channels on both sides of the lake. A portion of the west end of the sill is known to consist of rocky escarpments.

In addition to our 34 stations, sediment descriptions from samples taken on the sampling lines of Ayers and Hough (1964) were used to supplement our own observations. These lines, shown in Fig. 1, were roughly perpendicular

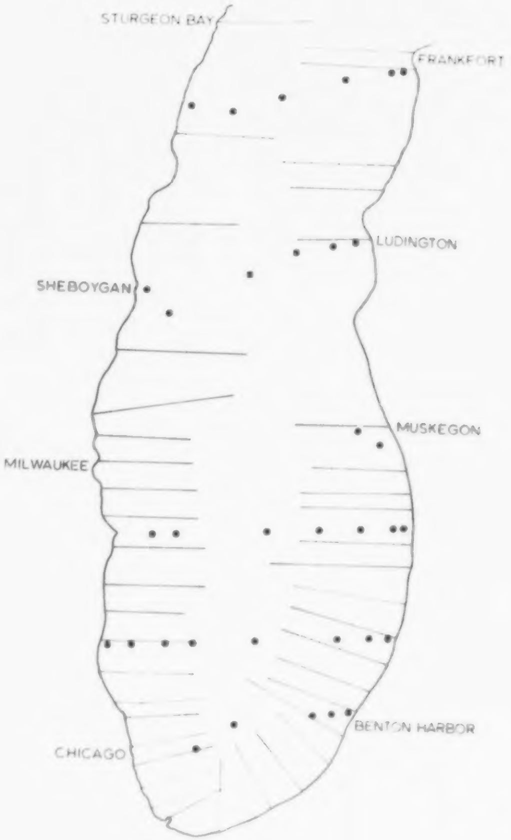

STURGEON BAY
FRANKFORT
LUDINGTON
SHEBOYGAN
MUSKEGON
MILWAUKEE
BENTON HARBOR
CHICAGO

FIG. 1. Locations of stations and sampling lines, Lake Michigan.

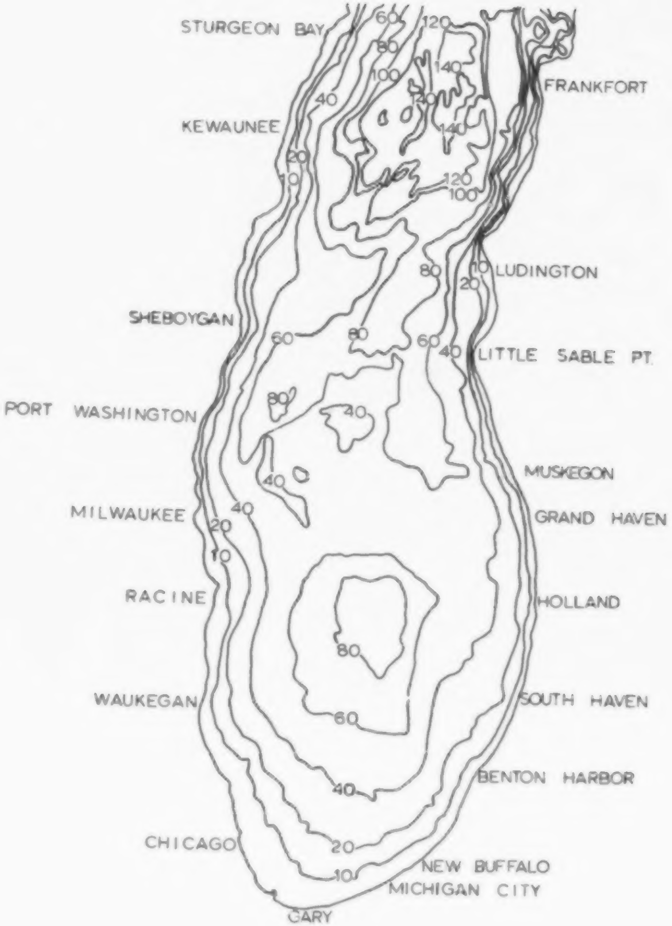

STURGEON BAY
FRANKFORT
KEWAUNEE
LUDINGTON
SHEBOYGAN
LITTLE SABLE PT.
PORT WASHINGTON
MUSKEGON
MILWAUKEE
GRAND HAVEN
RACINE
HOLLAND
WAUKEGAN
SOUTH HAVEN
BENTON HARBOR
CHICAGO
NEW BUFFALO
MICHIGAN CITY
GARY
10
20
40
60
80
100
120
140

FIG. 2. Orientation map and bathymetry of Lake Michigan. Depths in fathoms.

to shore and from 5 to 15 miles apart. On each line samples were usually taken as follows: at one-mile intervals from the 1st through the 10th mile from the beach, at 2-mile intervals from the 10th through the 20th mile, and at 5-mile intervals thereafter. A single grab sample of the surficial sediment was obtained at each station and described as outlined above.

Particle size analyses have been conducted on the part of these samples taken in the southern basin, south of the Milwaukee-Muskegon region. Analyses for the west half of the lake were made by Paul Josephson, Great Lakes Research Division (personal communication), and from the east half by Cote (1967). The percentages of sand, silt, and clay from the results of these analyses have been used to assign soil-type nomenclature to each sample after the method of Shepard and Moore (1955) which was also used by Lauff _et al_. (1961) in studies of the Straits of Mackinac region. The results obtained in this way were then compared with the visual descriptions made in the field. These comparisons showed that our field descriptions were reliable within limits. The following four categories appeared to be rather consistently discernible through field description: sand ("clean," beach-type sand), silty sand-sandy silt, silt-clayey silt, and silt-clayey silt overlying stiff plastic clay. The silt-clayey silt layer of the latter sediment type is generally quite thin, varying from about one-sixteenth inch to one inch in depth.

For simplicity, these four categories will hereafter be referred to, respectively, as sand, silty sand, silt, and layered. Silty sand and sandy silt are combined, as are silt and clayey silt, because the members of these pairs are very difficult, if not impossible, to differentiate visually in the field. Stiff clay, of course, is readily identified, but the non-compacted clays, usually gray in color and quite soft and soupy, are difficult to separate visually from silt.

Sediment samples for the determination of organic carbon were taken in triplicate at each station in July and October 1965 and in April 1966, to obtain estimates of this parameter on a seasonal basis. A short gravity corer of 2-inch (5 cm) inside diameter was used in July, and a Ponar grab sampler the other two months.

The corer was designed to accept removable plastic liners so that extrusion of cores in the field was not necessary. Each liner, while being maintained in a vertical position, was removed from the core barrel and quickly corked at the bottom. The core was left upright for a sufficient time to permit resettling of the surficial sediment, after which the supernatent water was drained by drilling a small hole through the liner a short distance above the top of the sediment. A second cork was then pushed down to the top of the sediment. The excess liner was cut off, and the core immediately frozen at about -20°C.

Initially it was thought that the corer would obtain a more representative, more nearly undisturbed section of the sediment-water interface than the grab sampler, particularly since the sediment would be contained in a plastic core liner which would eliminate the need for subsampling. However, the use of a corer is a tedious, time-consuming technique, and accurate removal of a representative sample from the top for analysis, after thawing in the laboratory, was found to be difficult owing to considerable slumping of the sedimentary material. It was therefore decided to attempt the October sampling with a Ponar. Triplicate grab samples were taken at each station, and from each a subsample was removed with a spatula from the top 2 cm of sediment. In the case of layered sediment, only the top layer was subsampled. Each subsample was sealed in a small plastic bag and frozen. The April samples were taken in the same manner. Determinations of organic carbon were performed ashore using the "wet oxidation" method of Grewling and Peech (1960). As will be shown later, no differences in organic carbon content were found between samples taken with the corer and those taken with the Ponar.

## DISTRIBUTION OF THE BOTTOM SEDIMENTS

The locations of the stations on Hough and Ayers' sampling lines and of our 34 stations were plotted on a navigation chart of Lake Michigan. The corresponding sediment type, following the nomenclature described in the preceding section, was entered at each station location. From the resulting distribution of known sediment types the major boundaries of sand, silty-sand, silt, and layered sediment were interpolated to produce the sediment map shown in Fig. 3. Precise location of boundaries was not, of course, always possible, but enough data points existed to permit reasonable estimation. Data points for the northern basin of the lake were considerably less dense than for the southern basin. The bathymetry of the lake was sometimes utilized as an additional guide in the estimation of most probable boundaries of sediment types in the northern part.

Establishment of the boundaries resulted in a representation of the distribution of the four sediment types: sand, silty sand, layered, and silt. In additon, it was determined that a fifth category, defined simply as "hard," should be added to account for the nature of the lake bottom in the southern and western parts of the lake, between Waukegan and Gary, and nearshore between Milwaukee and Racine. In those regions the bottom consists of such materials as glacial till, gravel, and cobbles and boulders.

Inspection of the sediment map shows that sand and silty sand are typical nearshore, shallow water sediments restricted to narrow bands extending almost continuously around the shores of the study area. The continuity is interrupted in the two areas of hard bottom off Milwaukee-Racine and Waukegan-Gary.

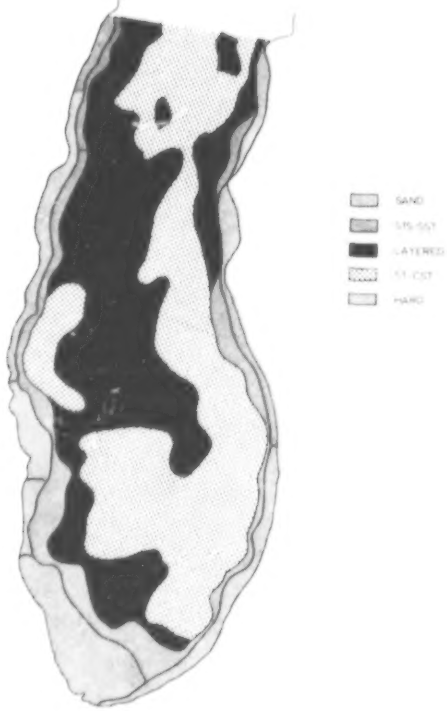


FIG. 3. Distribution of sediment types in Lake Michigan.

The predominant bottom types in the lake are layered sediment and silt, both of which are found almost exclusively at depths greater than 50 m (27 fm). The relative distribution of the two sediment types is not the same in the northern and southern basins. It can be seen from Fig. 3 that north of the sill layered sediment occupys a greater area of lake bottom than does silt, which is restricted to the deep basins and channels. Most of the western part of the northern basin consists of layered bottom, except for the shoreward bands of sand and silty sand and a restricted area of silt occupying an arc-shaped trench between Sheboygan and Milwaukee. Silt occurs in the very deep water between Frankfort and Kewaunee, where the deepest soundings in Lake Michigan (up to 282 m; 154 fm) are found, and is continuous over the sill and into the southern basin through the channel which extends down the eastern side of the lake. A narrow band of layered sediment lies on the shoreward side of the silt zone between Frankfort and Little Sable Point, and extends shoreward to the boundary of the sands. Silty sand in that region is limited to a small lens north of Ludington. This is the only interruption found in the band of silty sand, which otherwise extends continuously around the lake from Frankfort to Sturgeon Bay.

Whereas silt in the northern basin is found only in deep water, south of the sill it extends into depths as shallow as 50 m (27 fm). The isobaths in the southern basin tend to describe a lopsided saucer (Fig. 2) having its greatest depth in midlake between Holland and Racine. The distribution of silt, however, does not conform to this topography. Off shore from the narrow coastal strips of sand and silty sand, a band of silt occupies the eastern one-third of the basin as far south as the region off Benton Harbor. Between, roughly, Holland and South Haven, the silt region extends into and somewhat beyond midlake to occupy the deeper portion of the basin.

The occurrence of layered sediment is greatly restricted in the southern part of the lake, appearing as a narrow band which extends from the northern basin down the western side of the lake until, off Waukegan, it turns southeast and terminates off New Buffalo. Layered sediment also protrudes across the sill in the east central part of the lake off Holland, but extends only a short distance into the southern basin.

Silty sand on the west and south sides of the southern basin lies farther off shore, for the most part, than anywhere else in the lake. It is separated from the shore by extensive areas of hard bottom between Milwaukee and Michigan City except for a short stretch of sand between Racine and Waukegan. In this latter region the silty sand belt approaches shore more closely than off the areas of hard bottom.

## ORGANIC MATTER IN THE SEDIMENTS

Organic carbon determinations were made on sediment samples taken at our 34 stations as a measure of the quantity of organic matter incorporated into the surficial bottom deposits of the lake. Triplicate samples were taken at each station in April, July, and October and analyzed for carbon content in order to ascertain whether significant seasonal differences occurred. The results, as averages of the triplicates, appear in Table 1.

A Friedman two-way analysis of variance by rank test (Siegel 1956) was performed on the three sets of data to determine if the percent organic carbon was different at the different seasons. No differences were found at the 5% significance level ($\chi_r^2 = 0.26$, $N = 31$, $df = 2$, $p > 0.80$).

The interrelation among sediment type, organic carbon, and depth is shown in Fig. 4. It is evident that organic carbon generally increases with depth, but the increase is not uniform and is influenced by sediment type. The smallest quantities of organic carbon occur in sand, which is found only in shallow water. Sand is found at depths up to 44 m (24 fm) and its carbon values range between 0.06 and 0.22%. Silty sand overlaps in depth with sand, but extends into deeper water, to 94 m (51 fm) off Muskegon. Its organic

TABLE 1. Relation of sediment types, organic carbon, and depth in Lake Michigan, July, October, 1965; April, 1966. Positions of the stations appear in Fig. 1; latitude and longitude of each appear in Robertson and Alley (1966).

| Station | Depth (m) | July | October | April | Average | Sediment Type |
|---|---|---|---|---|---|---|
| A-1 | 18 | 0.08 | 0.04 | 0.01 | 0.06 | Sand |
| A-2 | 35 | 0.96 | 0.64 | 0.53 | 0.71 | Silty sand-sandy silt |
| A-3 | 70 | 1.83 | 1.82 | 1.74 | 1.80 | Silt-clayey silt |
| A-4 | 74 | 1.05 | 2.90 | 1.13 | 1.69 | Layered |
| A-5 | 43 | 0.22 | 0.10 | 0.17 | 0.16 | Silty sand; sand and gravel |
| | | | | | | |
| B-1 | 19 | 0.30 | 0.05 | 0.02 | 0.12 | Sand |
| B-2 | 47 | 1.72 | 1.66 | 1.73 | 1.70 | Silt-clayey silt |
| B-3 | 68 | 2.78 | 2.22 | 3.12 | 2.71 | Silt-clayey silt |
| B-4 | 129 | 2.57 | 3.11 | 3.34 | 3.01 | Silt-clayey silt |
| B-5 | 108 | 2.20 | 2.40 | 2.88 | 2.49 | Silt-clayey silt |
| B-6 | 83 | 0.96 | 1.26 | 1.54 | 1.25 | Layered |
| B-7 | 45 | 0.19 | 0.44 | 0.47 | 0.37 | Silty sand-sandy silt |
| B-8 | 11 | 0.09 | 0.15 | 0.13 | 0.12 | Sand |
| | | | | | | |
| C-1 | 20 | 0.23 | 0.07 | 0.03 | 0.11 | Sand |
| C-2 | 50 | 2.20 | 1.60 | 1.34 | 1.71 | Silt-clayey silt |
| C-3 | 77 | 2.50 | 3.11 | 2.73 | 2.78 | Silt-clayey silt |
| C-4 | 108 | 1.22 | 1.12 | 2.51 | 1.62 | Layered |
| C-5 | 157 | 2.13 | 3.17 | 3.76 | 3.02 | Silt-clayey silt |
| C-6 | 99 | 0.72 | 0.64 | 0.61 | 0.66 | Layered |
| C-7 | 55 | 0.29 | 0.27 | 0.23 | 0.26 | Silty sand-sandy silt |
| | | | | | | |
| C'-1 | 38 | 0.53 | 0.46 | -- | 0.50 | Silty sand-sandy silt |
| C'-2 | 93 | 0.61 | 0.44 | -- | 0.52 | Silty sand-sandy silt |
| | | | | | | |
| D-1 | 30 | 0.07 | 0.11 | 0.03 | 0.07 | Sand |
| D-2 | 98 | 0.74 | 1.15 | 0.81 | 0.90 | Layered |
| D-3 | 170 | -- | 3.60 | 3.43 | 3.52 | Silt-clayey silt |
| D-4 | 131 | 0.72 | 0.79 | 0.75 | 0.75 | Layered |
| D-5 | 119 | 0.61 | 0.60 | 0.83 | 0.68 | Layered |
| D-6 | 30 | 0.24 | 0.19 | 0.20 | 0.21 | Sand |
| | | | | | | |
| E-1 | 44 | 0.50 | 0.10 | 0.05 | 0.22 | Sand |
| E-2 | 197 | 3.73 | 3.08 | 3.07 | 3.29 | Silt-clayey silt |
| E-3 | 271 | 3.47 | 3.31 | 3.86 | 3.55 | Silt-clayey silt |
| E-4 | 216 | 2.21 | 3.72 | 3.24 | 3.06 | Silt-clayey silt; layered |
| E-5 | 173 | 4.07 | 3.91 | 4.08 | 4.02 | Silt-clayey silt |
| E-6 | 33 | 0.27 | 0.19 | 0.14 | 0.20 | Sand |

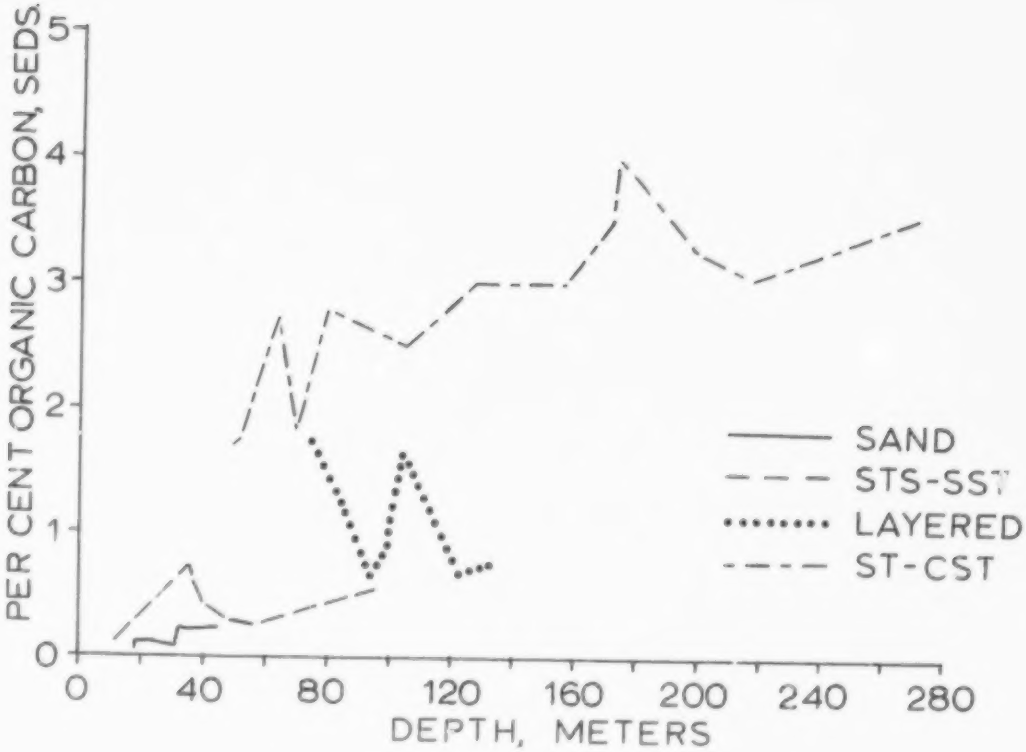


FIG. 4. Interrelations of sediment type, carbon, and depth in Lake Michigan.

carbon content slightly overlaps that of the sand but, in general, is higher, ranging between 0.12 and 0.71%. Layered sediment is found in intermediate depths between 74 and 132 m (40 and 72 fm), and the organic carbon in its upper layer exhibits values ranging from 0.66 to 1.25%. Silt completely overlaps the depth range of the layered sediment, being found as shallow as 48 and 52 m (26 and 28 fm) off South Haven and Holland. At depths over 132 m (72 fm) it is the only bottom type encountered and is the characteristic sediment of all the deeper parts of the lake. It exhibits the highest quantities of organic carbon, from about 1.70% at 48 and 52 m to 4.02% at 173 m (95 fm) in the northern basin. The carbon values at depths greater than 170 m (93 fm) are the highest found.

## SEDIMENTARY ORGANIC MATTER IN LAKES SUPERIOR AND HURON

We obtained a limited amount of data in July 1966 on the occurrence of organic carbon in the sediments of Lakes Huron and Superior. Triplicate sediment samples were taken at 10 stations in northern Lake Huron and at 7 stations in eastern Lake Superior (Fig. 5). Seven of the Lake Michigan stations sampled previously (stations C-1 through C-7) were resampled at the same time for comparative purposes. The July 1966 observations for all three lakes are summarized in Table 2. Station HU-10 was at the greatest depth in Lake Huron, 227 m (124 fm), while SU-6 in Lake Superior was at 362 m (198 fm), a depth not greatly less than the deepest sounding in that lake of 406 m (222 fm).

In Fig. 6 organic carbon has been plotted as a function of depth for Lakes Superior, Huron, and Michigan. It is evident that the relation of organic carbon to depth is essentially the same in the sediments of all three lakes. The maximum levels of organic carbon are about the same, between 3 and 4%. Further, the highest carbon values in each lake were in silt-clayey silt, which was found to be the characteristic deep water sediment in Superior and Huron as well as Michigan. A leveling-off of carbon values in the 3-4% range at about 90-100 m (49-55 fm) is an interesting feature which was observed in all three lakes. No appreciable increase in organic carbon content was discernible beyond that depth.

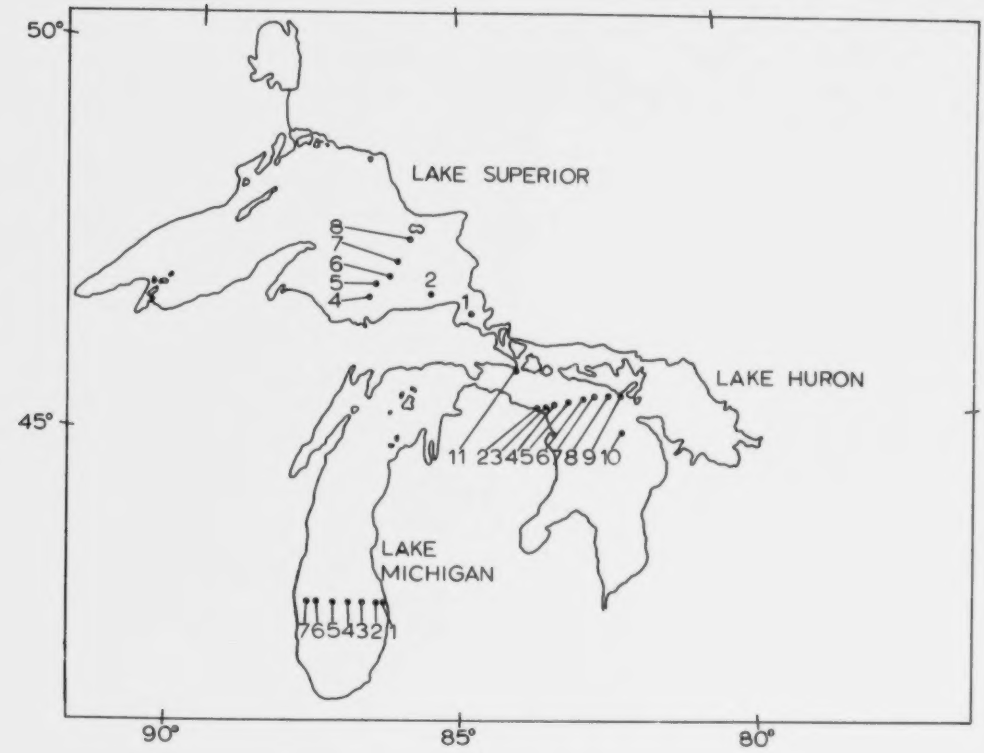
A considerable number of stations varying in depth from 97 to 362 m (53 to 198 fm) possessed sediment with an organic carbon content between 3 and 4%. The sediment type at each of these stations was silt. On the other hand, two values for Lake Superior, lying at 207 and 226 m, appear anomalously low for those depths with values of 0.76 and 1.01%. These samples, however, although taken from relatively great depths, were from the side of a steep slope and contained layered sediment. It was noted for Lake Michigan that the carbon content of the top layer of layered sediment is low, and these two values from Lake Superior layered sediment lie within the range for the same sediment type in Lake Michigan.

## DISCUSSION

The analysis of the distribution of bottom types as presented here is from the point of view of the biologist attempting to discern interrelationships of sediment, organic matter, bottom topography, and water depth which may have significant ecological implications. From the standpoint of the geologist the breakdown of the sediments into sand, silty sand-sandy silt, "layered," and silt-clayey silt (plus "hard") is undoubtedly a gross oversimplification. However, these are categories which can be recognized in the field by the biologist and are quantitatively definable in terms of

TABLE 2. Relation of sediment types, organic carbon, and depth in Lakes Michigan, Huron, and Superior, July, 1966.

| Station | Depth (m) | Latitude | Longitude | % Organic C | Sediment Type |
|---|---|---|---|---|---|
| C-1 | 25 | 42°49'40" | 86°14'50" | 0.05 | Sand |
| C-2 | 53 | 42°49'40" | 86°18'25" | 1.33 | Silt-clayey silt |
| C-3 | 80 | 42°49'10" | 86°28'25" | 1.84 | Silt-clayey silt |
| C-4 | 100 | 42°48'50" | 86°41'30" | 2.06 | Layered |
| C-5 | 162 | 42°49'00" | 86°50'00" | 3.44 | Silt-clayey silt |
| C-6 | 100 | 42°47'40" | 87°26'50" | 0.77 | Layered |
| C-7 | 54 | 42°47'30" | 87°34'30" | 0.24 | Silty sand-sandy silt |
| HU-2 | 21 | 45°25'12" | 83°41'48" | 0.02 | Layered |
| HU-3 | 65 | 45°25'48" | 83°31'12" | 0.42 | Silty sand-sandy silt/clay |
| HU-4 | 102 | 45°27'00" | 83°12'12" | 0.82 | Silty sand-sandy silt/clay |
| HU-5 | 86 | 45°27'54" | 82°56'48" | 2.27 | Layered |
| HU-6 | 141 | 45°28'42" | 82°43'18" | 1.70 | Layered |
| HU-7 | 123 | 45°30'54" | 82°27'06" | 2.35 | Sandy silt/silt-clayey silt |
| HU-8 | 72 | 45°31'30" | 82°16'30" | 1.91 | Layered |
| HU-9 | 27 | 45°32'15" | 82°02'54" | 0.15 | Sand/clay |
| HU-10 | 227 | 45°01'00" | 82°01'00" | 3.47 | Silt-clayey silt |
| HU-11 | 38 | 45°55'10" | 83°51'40" | 0.27 | Sand |
| SU-1 | 97 | 46°35'36" | 84°49'30" | 3.26 | Silt-clayey silt |
| SU-2 | 121 | 46°45'48" | 85°31'18" | 0.92 | Layered |
| SU-4 | 226 | 46°44'00" | 86°32'48" | 1.01 | Layered |
|  | 207 | 46°44'00" | 86°32'48" | 0.76 | Layered |
|  | 146 | 46°44'00" | 86°32'48" | 0.48 | Layered |
| SU-5 | 134 | 46°40'12" | 86°28'12" | 1.05 | Layered |
| SU-6 | 362 |  |  | 3.57 | Silt-clayey silt |
| SU-7 | 337 | 47°10'30" | 86°16'45" | 3.33 | Silt-clayey silt; layered |
| SU-8 | 112 | 47°37'54" | 85°49'48" | 0.60 | Sandy silt/clay |



50°
45°
90°
85°
80°
LAKE SUPERIOR
LAKE HURON
LAKE MICHIGAN
8
7
6
5
4
2
1
11 2345678910
7654321

FIG. 5. Locations of stations in Lakes Michigan, Huron, and Superior, July 1966.

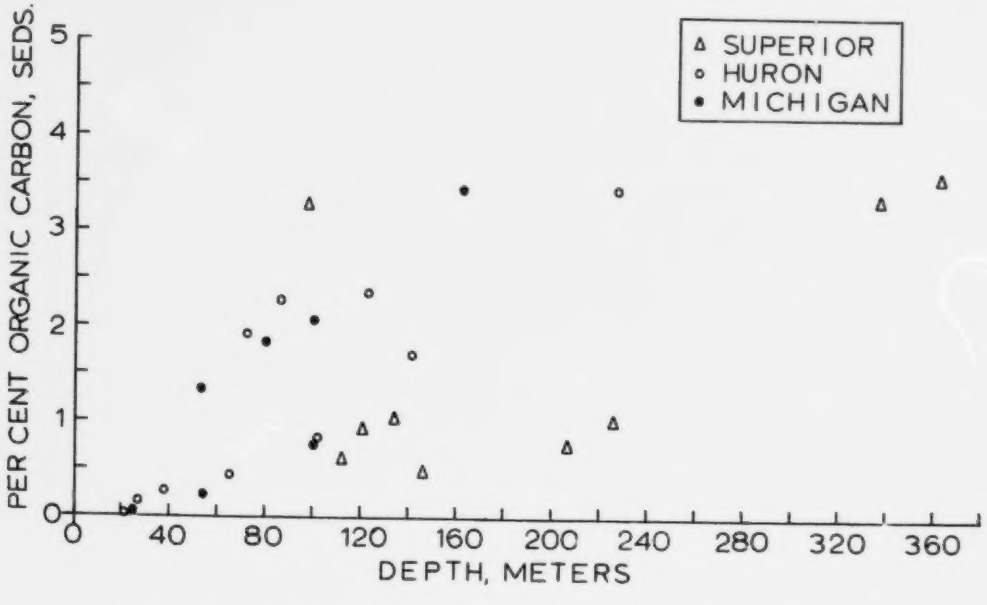


FIG. 6. Relation of organic carbon and depth in Lakes Michigan, Huron, and Superior, July 1966.

of percent sand, silt, and clay as determined by laboratory analysis. In view of the often haphazard descriptions of bottom types encountered in reports dealing with benthos, these qualities of recognizability and quantitative verification justify their usage.

The distribution of the four sediment types tends to be related to depth, although precise boundaries cannot be assigned to definite depth ranges. In Lake Michigan the depth range of silty sand completely overlaps that of sand, and silt completely overlays layered. There is also an overlap among the deep end of the silty sand, the shallow end of the silt, and the shallow end of the layered sediment. Within the zone of overlap, however, there is always a dominance of one or the other of the sediment types. Layered sediment predominates between 75 and 140 m (41 and 77 fm), silty sand is rarely found deeper than 60 m (33 fm), and sand was never found as deep as 50 m (27 fm). Except for a small area of layered sediment in midlake between Frankfort and Kewaunee, at about 270 m (148 fm), only silt is found at depths in excess of 140 m. It is possible, then, on the basis of depth alone, to predict with some accuracy the kind of bottom sediment that will be encountered. The principal exceptions are the eastern side of the southern basin, where silt extends into relatively shallow water, and the areas of hard bottom.

The difference in sediment distribution between the eastern and western parts of the southern basin has been pointed out. Whereas silt extends quite close to the eastern shore, into depths of about 50 m (27 fm), it is absent from the western side in depths less than about 90 m (50 fm). On the other hand, the silty sand belt is wider on the western side of the southern basin and extends farther into the lake than its east side counterpart. Further, the zones of hard bottom lying in the vicinity of Milwaukee-Racine and between Waukegan and Michigan City are peculiar to the west side. These anomalies in sediment distribution within the southern basin strongly suggest conditions of net deposition on the east side and net nondeposition on the west. Existing knowledge of circulation patterns in the lake is still sketchy, but Ayers et al. (1958), Bellaire (1964), and Verber (1966) have shown the existence of a large clockwise eddy which appears to occupy much of the eastern one-third of the southern basin. Such an eddy could constitute a mechanism for the deposition and accumulation of detrital materials on the lake bottom. In addition, all the major tributaries to the southern basin enter on the east side. These rivers are the Muskegon, entering at Muskegon, the Grand at Grand Haven, the Kalamazoo at Saugatuck, and the St. Joseph at Benton Harbor-St. Joseph. No tributaries of any consequence enter the southern end of the lake between Benton Harbor and Milwaukee. These four rivers are all large and at times carry heavy silt loads. It seems quite likely that they add significant quantities of material to the bottom sediments on their side of the lake and are thereby a contributing factor in the shoreward extension of silt on the east side of the basin. Cook and Powers (1964) showed that 3,660 tons of volatile suspended solids enter the lake annually from the St. Joseph River, and felt that it is reasonable to conclude that much of this settles to the lake bottom within a few miles of the harbor mouth.

It seems probable that the distribution of layered sediment is also related to current activity. Although it is found on steep slopes where slumping of surficial sediments might be invoked to explain the lack of accumulation of noncompacted sedimentary materials, layered sediment also covers large areas of the floor of Lake Michigan in which the topography does not suggest any such slippage of materials into deeper water. It appears, however, that horizontal currents of sufficient magnitude to transport sediment particle sizes at least as large as medium sand (0.25 mm on the Wentworth scale) occur at considerable depths in the lake. Verber (1965) carried out studies in which recording current meters were suspended in the lake to depths of 180 m during the winter of 1962-63 and the summer of 1963. He shows average currents of 4.7 cm/sec at 90 m, 3.2 cm/sec at 120 m, and 2.7 cm/sec at 180 m. Velocities in excess of 10 cm/sec were recorded at all of these depths at times. According to Sverdrup, Johnson and Fleming (1946, p. 961), particle sizes as large as 0.3 mm (larger than medium sand) will be transported by a current with a velocity of about 2.5 cm/sec. Velocities of about 15 cm/sec and greater are required for erosion, but those of the magnitude measured by Verber are more than sufficient to prevent deposition of suspended sedimentary material.

The quantity of organic carbon found in the sediments is closely related to sediment type and somewhat less so to depth. In Fig. 4 it can be seen that silty sand, layered sediment, and silt are all present in the depth range 48 to 94 m (26 to 51 fm). However, at these depths the organic carbon content is 0.26 and 0.52% for silty sand; 1.09, 1.25, and 0.66% for layered sediment; and 1.70, 1.71, 1.80, 2.71, and 2.78% for silt. Each sediment type exhibits its own range of organic carbon. Within sand, silty sand, and layered sediment there appears to be little relation between organic carbon content and depth when each sediment type is considered separately. There may be a slight positive relation in sand and silty sand, but obviously none at all in layered sediment. In silt, however, there is a definite tendency for the quantity of organic carbon to increase with depth. Even here, however, the trend is not completely uniform, with maximum values occurring at about 180 m (98 fm), nearly 100 m less than the maximum depth sampled.

The comparison of Lakes Michigan, Huron, and Superior with respect to organic carbon content of their sediments seems to indicate that there is little difference among the three lakes. In those cases where it was possible to sample deep isolated basins, the maximum in all cases was between 3 and 4%. Such a uniformity is surprising, since Robertson and Powers (1967) indicate that average production of organic matter in these lakes is not the same.

## CONCLUSIONS

Four principal bottom sediment types have been found in Lake Michigan. The distribution of these sediment types: sand, silty sand-sandy silt, silt-clayey silt, and silt-clayey silt over stiff plastic clay, appears to be related to depth, bottom topography, and, at least in Lake Michigan, to processes of deposition and nondeposition. Each of these sediment types can be characterized with respect to organic carbon content, although some overlap occurs. Generally, the percent organic carbon found in the shallower, sandy sediments is less than that in the deeper sediments composed of the finer silts and clays. The organic carbon content of the upper layer of layered sediment, however, is significantly less than that of silt-clayey silt, even where the two occur at comparable depths. This, coupled with the thinness of the upper silt layer of layered sediment, suggests a periodic removal of this layer by erosional forces, or, at least, an inhibition of deposition by horizontal water movements.

Limited investigations indicated that the basic sediment types found in Lake Michigan are also characteristic of Lakes Huron and Superior, and that the organic carbon content in comparable environments is about the same in all three lakes.

The relationships among sediment type, organic carbon, bottom topography, and depth provide an insight into the benthic environment which is fundamental to our understanding of the ecology of bottom-associated organisms. The relation of the macrobenthos of Lake Michigan to these and other physical-chemical factors will be considered in a further paper presently in preparation.

## REFERENCES

AYERS, J. C., D. C. CHANDLER, G. H. LAUFF, C. F. POWERS, and E. B. HENSON. 1958. Currents and water masses of Lake Michigan. Univ. Michigan, Great Lakes Res. Div. Pub. 3, 169 p.

__________, and J. L. HOUGH. 1964. Studies on water movements and sediments in southern Lake Michigan. Part II. The surficial bottom sediments in 1962-63. Univ. Michigan, Great Lakes Res. Div. Spec. Rpt. 19.

BELLAIRE, FRANK R. 1964. A comparison of methods of current determinations. Proc. 7th Conf. on Great Lakes Res., p. 171-178.

COOK, G. W., and R. E. POWERS. 1964. The benthic fauna of Lake Michigan as affected by the St. Joseph River. Proc. 7th Conf. on Great Lakes Res., p. 68-76.

COTE, WILLIAM E. 1967. Grain size analysis of sediments, southeastern Lake Michigan. M.S. Thesis, Univ. of Illinois, Urbana. 118 p.

EGGLETON, FRANK E. 1936. The deep-water bottom fauna of Lake Michigan. Pap. Mich. Acad. Sci., Vol. XXI, p. 599-612.

__________. 1937. Productivity of the profunal benthic zone in Lake Michigan. Pap. Mich. Acad. Sci., Vol. XXII, p. 593-611.

GREWLING, THOMAS, and MICHAEL PEECH. 1960. Chemical soil tests. Cornell Univ. Agric. Exp. Sta. Bull. 960.

HENSON, E. B., and H. B. HERRINGTON. 1965. Sphaeriidae (mollusca: Pelecypoda) of Lakes Huron and Michigan in the vicinity of the Staits of Mackinac. Proc. 8th Conf. on Great Lakes Res., p. 77-95.

LAUFF, G. H., E. B. HENSON, J. C. AYERS, D. C. CHANDLER, and C. F. POWERS. 1961. The bottom sediments of the Straits of Mackinac region. Univ. Michigan, Great Lakes Res. Div. Pub. 6, 69 p.

MC INTYRE, A. D. 1954. A spring-loaded bottom sampler. J. Mar. Biol. Assoc. U. K., _33_: 257-264.

MERNA, JAMES W. 1960. A benthological investigation of Lake Michigan. M.S. thesis, Mich. State Univ. Microfilm.

POWERS, CHARLES F., and ANDREW ROBERTSON. 1965. Some quantitative aspects of the macrobenthos of Lake Michigan. Proc. 8th Conf. on Great Lakes Res., p. 153-159.

__________, and __________. 1967. Design and evaluation of an all-purpose benthos sampler. (In this report.)

ROBERTSON, ANDREW, and WAYNE P. ALLEY. 1966. A comparative study of Lake Michigan macrobenthos. Limnology and Oceanography, _11_(4): 576-583.

__________, and CHARLES F. POWERS. 1967. Comparison of the distribution of organic matter in the five Great Lakes. (In this report.)

SCHUYTEMA, GERALD S., and ROSS E. POWERS. 1966. The distribution of benthic fauna in Lake Huron. Proc. 9th Conf. on Great Lakes Res., p. 155-163.

SHEPARD, F. P., and D. G. MOORE. 1955. Central Texas coast sedimentation: characteristics of sedimentary environment, recent history and diagenesis. Bul. Amer. Assoc. Petrol. Geol. _39_(8): 1463-1593.

SIEGEL, S. 1956. Nonparametric statistics: for the behavioral sciences. McGraw-Hill, New York. 312 p.

SVERDRUP, H. U., M. W. JOHNSON, and R. H. FLEMING. 1946. The oceans. Prentice-Hall, New York. 1060 p.

TETER, HAROLD E. 1960. The bottom fauna of Lake Huron. Trans. Am. Fish. Soc. 89(2): 193-197.

VERBER, JAMES L. 1965. Current profiles to depth in Lake Michigan. Proc. 8th Conf. on Great Lakes Res., p. 364-371.

__________. 1966. A study of Lake Michigan: chemical, biological, and physical. Proc., Internat. Assoc. Theor. and Appl. Limn., Vol. 16, Part 1, p. 29-46.

# RECENTLY NOTICED CHANGES IN THE BIOLOGY-CHEMISTRY OF LAKE MICHIGAN

John C. Ayers, E. F. Stoermer, and Paulette McWilliam

## INTRODUCTION

During mid and late August of 1966, a widespread occurrence of a milky water color was noticed in Lake Michigan. As seen over the white Secchi disc, this was a milky light blue or milky light green in contrast to the clear light blue or light green water color supposed to be the "normal" water color. The milky color was strikingly like that which had been observed in Lake Charlevoix and other marl-lakes. Water of this color was found in stations in five transects across the lake from Chicago to Frankfort, Michigan. In the milky water the Secchi disc transparency (disappearance depth of the 20-cm white disc) was reduced from the usual 6-14 m to 2-4 m.

Inquiry among the chief scientists of our cruises earlier in 1966 revealed that some occurrences of the milky color had been seen but not recorded. Inquiry among the sceientists of the Ann Arbor laboratory of the U.S. Bureau of Commerical Fisheries revealed that they remembered occurrences of the milky water color in Lake Michigan in recent years. The milky water-color was watched for during our cruises in September, October, and November 1966. It was still abundant over the southern two-thirds of the lake in September; vestiges of it were observed in all the parts of the lake covered in October; it was not observed during our November cruise. Figure 1 shows the area of the lake covered by each of our monthly cruises. Later in this paper the earlier data of the U.S. Bureau of Commerical Fisheries are used. Of these we have selected those that are south of the latitude of Frankfort, Michigan, and comparable to the area covered in our cruises.

Coincident with the milky water-color and reduced transparencies in August and September was the occurrence of dead adults of the deep-water shrimp, *Mysis relicta*. The dea shrimp and a concomitant oxygen undersaturation in the bottom water are discussed later.

## OBSERVATIONS

### MILKY WATER AND REDUCED TRANSPARENCIES

The drastically reduced Secchi transparencies that occurred with our recorded cases of milky water-color suggested that the considerably longer records of transparency could be examined for reduced values that might indicate the earlier unnoticed presences of milky water. The results of this investigation are shown in Table 1. In this study, any Secchi transparency of 5 m or less was considered to indicate the probable presence of milky water.

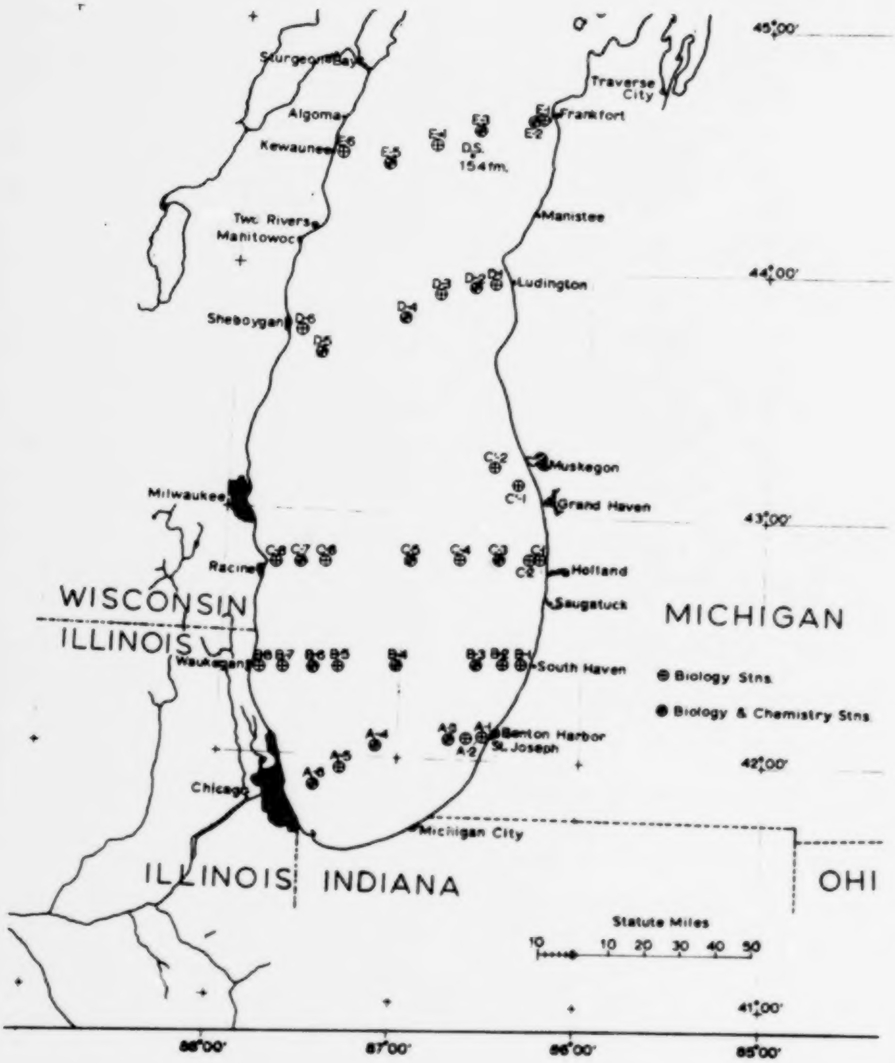

45°00'
44°00'
43°00'
42°00'
41°00'
88°00'
87°00'
86°00'
85°00'
Sturgeon Bay
Algoma
Kewaunee
Two Rivers
Manitowoc
Sheboygan
Milwaukee
Racine
Waukegan
Chicago
Michigan City
Traverse City
Frankfort
Manistee
Ludington
Muskegon
Grand Haven
Holland
Saugatuck
South Haven
Benton Harbor
St. Joseph
D.S. 154 fm.
E-1
E-2
E-3
E-4
E-5
E-6
D-1
D-2
D-3
D-4
D-5
D-6
C'-2
C'-1
C-8
C-7
C-6
C-5
C-4
C-3
C-2
C-1
B-8
B-7
B-6
B-5
B-4
B-3
B-2
B-1
A-1
A-2
A-3
A-4
A-5
A-6
WISCONSIN
ILLINOIS
MICHIGAN
ILLINOIS
INDIANA
OHI
⊕ Biology Stns
● Biology & Chemistry Stns
Statute Miles
10
10
20
30
40
50

FIG. 1. Sampling stations in Lake Michigan.

TABLE 1. Secchi disc transparencies, meters; inshore stations excluded.

| Year | Number of Observations | Transparencies | | | Number less than 5.1 m | Percent less than 5.1 m |
|---|---|---|---|---|---|---|
| | | Min | Max | Mean | | |
| All Stations | | | | | | |
| 1954* | 73 | 2.7 | 11.9 | 5.8 | 30 | 41 |
| 1955* | 39 | 4.0 | 12.5 | 6.8 | 10 | 26 |
| 1960* | 12 | 2.3 | 8.8 | 5.7 | 4 | 33 |
| 1961* | 18 | 2.7 | 18.3 | 6.7 | 5 | 28 |
| 1962 | 19 | 3.0 | 13.0 | 6.2 | 7 | 37 |
| 1963 | 14 | 5.0 | 9.0 | 7.0 | 2 | 14 |
| 1964 | 128 | 3.0 | 15.2 | 7.9 | 19 | 15 |
| 1965 | 105 | 3.0 | 15.0 | 7.1 | 27 | 26 |
| 1966 | 182 | 2.0 | 15.0 | 6.0 | 76 | 42 |
| Sampling Lines GA (off Gary) and NB (off New Buffalo)** | | | | | | |
| 1965 | 9 | 5.0 | 14.0 | 8.2 | 2 | 22 |
| 1966 | 16 | 3.5 | 8.2 | 5.7 | 9 | 56 |
| Sampling Line A (Chicago to Benton Harbor less Stations A-1 and A-6) | | | | | | |
| 1964 | 20 | 4.0 | 10.7 | 8.0 | 2 | 10 |
| 1965 | 21 | 3.5 | 11.0 | 6.9 | 7 | 33 |
| 1966 | 31 | 2.0 | 10.0 | 5.7 | 11 | 35 |
| Sampling Line B (Waukegan to South Haven less Stations B-1 and B-8) | | | | | | |
| 1964 | 26 | 3.0 | 11.5 | 7.9 | 4 | 15 |
| 1965 | 24 | 4.0 | 11.5 | 7.4 | 7 | 29 |
| 1966 | 19 | 3.2 | 10.0 | 6.7 | 5 | 26 |
| Sampling Line C (Racine to Holland less Stations C-1 and C-8) | | | | | | |
| 1964 | 23 | 4.0 | 15.2 | 8.6 | 2 | 9 |
| 1965 | 20 | 3.0 | 15.0 | 6.8 | 5 | 25 |
| 1966 | 51 | 2.0 | 15.0 | 5.8 | 24 | 47 |
| Sampling Line D (Sheboygan to Ludington less Stations D-1 and D-6) | | | | | | |
| 1964 | 26 | 3.0 | 13.0 | 7.1 | 7 | 27 |
| 1965 | 18 | 3.8 | 8.2 | 6.4 | 4 | 22 |
| 1966 | 15 | 4.0 | 9.0 | 6.2 | 4 | 27 |
| Sampling Line E (Kewaunee to Frankfort less Stations E-1 and E-6) | | | | | | |
| 1964 | 25 | 4.0 | 14.0 | 7.8 | 4 | 16 |
| 1965 | 23 | 5.0 | 12.5 | 7.8 | 3 | 13 |
| 1966 | 35 | 2.5 | 12.0 | 6.9 | 10 | 29 |

*Data of U.S. Bureau of Commercial Fisheries (Beeton and Moffett 1964).
**Less stations GA-1 and NB-1.

From the percentage column of Table 1 it appears that 1954 and 1966 were years of widespread occurrence of the milky-water condition. These indications are strongly supported in the minimum- and mean-transparency columns. Also indicated in the percentage column (and supported by the minimum- and mean-transparency columns) are indications that milky water probably occurred in 1960 and 1962; the few observations in these years preclude any firmer statement. Perhaps the most significant materials in Table 1 are the worsening conditions from 1964 through 1966 in all stations and in the individual sampling lines.

In March 1967 the senior author observed abundant milky-water conditions in sampling lines A, GA, and NB.

## NORMAL VS. ACIDIFIED TURBIDITIES

Bothered by the similarity of the color of the milky water to that of known marl-lakes, the senior author conducted some preliminary turbidity experiments during a short cruise in September 1966.

Normal turbidities in surface and near-bottom water were read on the Hellige turbidimeter in the usual manner, then 5 ml of concentrated hydrochloric acid were added to the sample while it was still in the Hellige sample cell and the turbidity read again after stirring. The results of these tests are shown in Table 2.

TABLE 2. Normal vs. acidified Hellige turbidities, 19-21 September 1966.*

| Station | Secchi transparency, m | Water color | Depth of sample, m | Hellige turbuidity, ppm | |
|---|---|---|---|---|---|
| | | | | Normal | Acidified |
| AEC-1 | 4.5 | Milky | 0 | 3.0 | 1.5 |
| | | | 160 | 3.0 | 1.5 |
| AEC-2 | 4.5 | Milky | 0 | 4.3 | 3.0 |
| | | | 150 | 7.5 | 1.5 |
| AEC-3 | 3.5 | Milky | 0 | 2.0 | 2.0 |
| | | | 122 | 8.7 | 5.6 |
| AEC-4 | 4.0 | Milky | 0 | 2.5 | 1.3 |
| | | | 172 | 4.3 | 3.3 |
| AEC-5 | 6.0 | Clear | 0 | 2.9 | 2.5 |
| | | | 170 | 3.3 | (5.0)? |
| AEC-6 | 3.8 | Milky | 0 | 4.5 | 3.3 |
| | | | 234 | 3.0 | 1.3 |

*All samples by Nansen bottle.

The positions of these stations are given in a later table; in reference to Fig. 1 they extended from near B-4 in the deep part of the southern basin through approximately C-5, C-3, C'-1, C'-2 and D-3 to near E-4 in the deep part of the north basin.

Despite the preliminary nature of the above results, there is sufficient evidence to support a suspicion that the milky water-color was associated with materials that contributed to the turbidity and were at least in part acid-soluble.

## SUSPENDED PARTICLES

At each of the AEC stations 60 ml each of surface and near-bottom water were centrifuged in a small laboratory centrifuge. All the samples yielded small white particles similar to chalk-dust. Water from AEC-3 surface, AEC-4 surface and bottom, and AEC-5 bottom contained very few particles. Water from AEC-3 bottom, AEC-5 surface, AEC-6 surface and bottom, and AEC-7 surface contained moderate amounts of particles. One Nansen bottle cast from 8 m off bottom at AEC-7 had a Hellige turbidity of 23.0 ppm and centrifuged out a heavy population of particles; the duplicate cast to the same depth had a turbidity of 2.5 and centrifuged only a few particles. Ship drift between casts is believed to be the cause of the difference.

## THE FINDINGS AT CHICAGO, 1956-61

Vaughn (1961) reported several findings that have a striking similarity to our recent results. Beginning in the winter of 1956-57 the Chicago South District Filtration plant was plagued with the passage of a fine turbidity through its filters. In the early months of 1958 this condition was accompanied by a noticeable rise in the pH of the raw water. In 1959 an acute turbidity-passage condition lasted from 16 January through 30 April. In 1960 the condition occurred again for a short period. In 1961 the condition appeared on 24 January and was present at the time of writing on 30 May.

The condition of turbidity passage was finally correlated with outbursts of the diatom, Stephanodiscus hantzschii, as also were the abnormally high pH conditions. On 1 May 1961 a survey of the region produced the following:

| Location | pH | Numbers per ml<br>Stephanodiscus hantzschii |
|---|---|---|
| Off Dunne Crib | 8.79 | 6750 |
| Off Calumet Harbor entrance | 8.50 | 2100 |
| Off Hammond Water Plant intake | 8.41 | 1500 |
| Off Indiana Harbor Ship Canal entrance | 7.50 | 700 |

By May of 1961 cuboidal crystals believed to be calcium carbonate had been collected from both finished and raw water. As a check on the possible presence of increased amounts of calcium carbonate in the raw water, the raw-water phenolphthalein alkalinities were tabulated from 24 June (sic) (24 January, the beginning of that year's turbidity condition?) to 16 May 1961. The alkalinities, which normally ranged from 1.0 to 4.0 ppm, were in this period from 2.6 to 11.0 ppm, indicating a range of 5.2 to 22.0 ppm calcium carbonate. The maximum phenolphthalein alkalinity of 11.0 ppm occurred with a pH of 8.65.

The conclusion reached at Chicago was that the high population of diatoms uses up the trace amounts of dissolved free carbon dioxide and turns to the next available source, calcium bicarbonate, producing calcium carbonate as a by-product. This could cause the observed turbidity and raise the phenolphthalein alkalinity, and in conjuction with decreased carbonic acid, produce the increase in pH.

It should be mentioned that in December 1960 a new filamentous diatom occurred at Chicago and since January 1961 has caused shortened winter and spring filter runs at the South District Filtration Plant. This diatom was Stephanodiscus (Melosira?) binderanus.

There are, then, two winter-spring blooming diatoms in the Chicago region that could have contributed to the milky water condition observed there in March of 1967.

## DISSOLVED OXYGEN

The similarity of the milky water-color to that of marl-lakes prompted us to examine the dissolved oxygen content of the lake water. Behind this decision was the thought that the reduced transparency of the water might be reducing the penetration of light sufficiently to influence the hypolimnetic oxygen content. The pressure of other duties did not allow the determination of oxygen on full Nansen casts but duplicate-cast surface and bottom samples were run at several stations. Oxygen was determined by the Alsterberg modification of the Winkler method and oxygen saturation was read from the nomogram of Mortimer as given by Hutchinson (1957, p 582). The oxygen values obtained in late September and early October are given in Table 3.

For comparison, those late September and early October stations of Beeton and Moffett (1964) which were at the latitude of Frankfort or farther south are shown in Table 4. Only the nearest-to-bottom Nansen bottle samples are used. Inshore stations were excluded.

Comparisons between these two tables suggest a diminution in dissolved oxygen in the decade since the 1950's. In 1954-55, 45% of the oxygen content values equaled or exceeded 11.0 ppm; in 1966 the percentage was 10%. In 1954-55 the oxygen saturation equaled or exceeded 90.0% in 35% of the cases; in 1966 the percentage was 10%. If the two A-line stations of 1966 are omitted, because they are farther south than the older surveys reached, the two 1966 percentages become 12.5% each.

From these data it appears that statistical consideration of oxygen levels in the near-bottom water may be a sensitive means for detection of, or monitoring for, small changes in the trophic stage of Lake Michigan.

## DEAD MYSIS RELICTA

Dead Mysis were first collected on 19 September 1966 when a vertical haul of the half-meter #20 plankton net captured more than 50 mysids. The large number prompted closer examination of the sample, for the net had been fished slowly from near bottom to the surface and the strong-swimming mysids commonly avoid it. Examination revealed that many of the mysids were abnormally still and that among them there were numerous individuals of adult or near-adult size that were of a thick opaque white color very different from the nearly-transparent living condition. The opaque white color was identical to that assumed by preserved specimens of the species. It was evident that the white individuals were dead.

Overhearing the discussion, one of the technicians volunteered that he had seen similar white mysids in the plankton samples of the August cruise. Dead mysids were collected at the AEC stations in mid and late September. The last to be found were taken in early October when 13 flattened, ragged, and obviously decomposing adults were found lying on the surface of Ponar (grab-sampler) sediment samples.

In Table 5 are presented our notes relative to the collections of dead mysids. These are shipboard notes from inspections of fresh collections in their containers. That more detailed examinations were not made and better records were not taken was due to the fact that we did not know at the time that these appear to be the first collections of dead mysids from Lake Michigan.

TABLE 3. Oxygen contents and saturations, 20 September-2 October 1966. AEC samples by Nansen bottle; others by bottom-tripped Van Dorn bottle.

| Station | Sample Depth | Temperature, °C | $O_2$ mg/l | $O_2$ % Saturation |
|---|---|---|---|---|
| AEC-4<br>(177 m) | Surface | 17.2 | 9.4 | 102 |
| | 5 m off bottom | 3.8 | 10.4 | 82 |
| AEC-5<br>(171 m) | Surface | 13.5 | 9.5 | 95 |
| | 1 m off bottom | 4.7 | 10.5 | 84 |
| AEC-6<br>(236 m) | Surface | 18.0 | 9.1 | 100 |
| | 2 m off bottom | 4.2 | 10.9 | 87 |
| AEC-7<br>(278 m) | Surface | 18.5 | 9.0 | 100 |
| | 8 m off bottom | 4.2 | 10.8 | 86 |
| A-3<br>(68 m) | 18" off bottom | 5.5 | 8.1 | 67 |
| A-4<br>(135 m) | 18" off bottom | 4.0 | 9.8 | 77 |
| C-3<br>(81 m) | 18" off bottom | 4.4 | 10.5 | 84 |
| C-5<br>(152 m) | 18" off bottom | 4.4 | 11.6 | 92 |
| C-7<br>(54 m) | 18" off bottom | 6.5 | 8.5 | 72 |
| E-5<br>(177 m) | 18" off bottom | 4.3 | 10.6 | 84 |

TABLE 4. Oxygen contents and saturations, late September-early October, 1954-55 and 1960-61. Data of Beeton and Moffett (1964).

| Station | Sample Depth | Temperature, °C | $O_2$ ppm | $O_2$ % Saturation |
|---|---|---|---|---|
| 1954 | | | | |
| 13 | 3 m off bottom | 4.1 | 10.5 | 83 |
| 12 | 0.4 m off bottom | 4.4 | 10.8 | 86 |
| 11 | 3 m off bottom | 4.3 | 9.0 | 73 |
| 14 | 5 m off bottom | 4.4 | 10.6 | 85 |
| 15 | 0.3 m off bottom | 3.8 | 11.0 | 86 |
| 19 | 3 m off bottom | 4.8 | 9.9 | 80 |
| 18 | ---- | 4.1 | 10.9 | 87 |
| 17 | 3 m off bottom | 4.7 | 9.7 | 78 |
| 13 | 3 m off bottom | 4.4 | 10.0 | 80 |
| 12 | 0.4 m off bottom | 4.2 | 11.3 | 90 |
| 11 | 3 m off bottom | 4.3 | 10.9 | 87 |
| 1 | 3 m off bottom | 4.3 | 11.4 | 91 |
| 2 | ---- | 3.9 | 12.0 | 95 |
| 3 | 3 m off bottom | 4.4 | 11.3 | 90 |
| 1955 | | | | |
| 34 | 3 m off bottom | 3.8 | 10.9 | 86 |
| 33 | 15 m off bottom | 3.75 | 11.7 | 92 |
| 32 | 3 m off bottom | 5.0 | 11.0 | 94 |
| 1 | 3 m off bottom | 4.7 | 11.2 | 90 |
| 2 | 11 m off bottom | 3.9 | 10.7 | 83 |
| 3 | 3 m off bottom | 3.95 | 11.2 | 88 |
| 1960 | | | | |
| 12d | 3 m off bottom | 4.1 | 9.7 | 97 |
| 1961 | | | | |
| 8f | 3 m off bottom | 4.5 | 10.8 | 86 |
| 8g | 9 m off bottom | 3.65 | 10.5 | 82 |
| 7d | 3 m off bottom | 6.6 | 10.6 | 90 |
| 8f | 2 m off bottom | 3.9 | 9.7 | 76 |

During the winter of 1966-67 the original AEC samples were carefully handpicked for mysids. These were subjected to microscopic examination by the junior author in the spring of 1967. Since these were the very specimens that were first collected, it is deemed of at least historical interest that they be reported as completely as possible.

The preserved collections were examined for age composition, for spent (spawned) adults, and for morphological characteristics unusual enough to indicate that the individual might have been dead before preservation. The results of the microscopic examination are shown in Table 6.

TABLE 5. Collections of dead mysids, September-October 1966. Based on shipboard notes of the unpreserved collections.

| Station | Position | Collecting device | Numbers | Comments |
|---|---|---|---|---|
| AEC-1 | 42°36.0',86°59.0' | #20 net | over 50 | dead adults seen |
| AEC-2 | 42°46.5',87°02.5' | #20 net | est. 40 | dead adults seen |
| AEC-3 | 43°18.5',86°42.5' | #20 net | 3 | 2 dead adults, one fragment |
| AEC-4 | 43°54.4',86°49.9' | #20 net | about 50 | dead adults seen |
| AEC-5 | 44°08.7',86°42.6' | #20 net | 2 | dead adults, plus fragments |
| AEC-6 | 44°20.0',86°40.0' | #20 net | over 10<br>over 10 | dead adults<br>separate abdomens |
| AEC-7 | 44°28.7',86°43.1' | #20 net | over 75 | dead adults seen |
| E-2 | 44°37.0',86°21.7' | Ponar | 6 | dead adults, on bottom |
| E-3 | 44°34.0',86°40.0' | Ponar | 3 | dead adults, on bottom |
|  |  | Sled-net | a few | dead adults, among live of all sizes |
| E-4 | 44°30.3',86°55.3' | Ponar | 4 | dead adults, on bottom |
|  |  | #20 net | est. 5 | dead adults, among living |
| E-5 | 44°25.5',87°10.3' | #20 net | est. 5 | dead adults plus pieces, among living |
|  |  | Sled-net | 1 | dead adult plus pieces among living |

TABLE 6. Annotated counts of the AEC mysid collections. The lower line in each station represents those that were "presumed dead before fixation" because of peculiar features.

| Station | Mature | | Near Maturity | | Immature | | Juvenile | Total Number | "Spent" | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Males | Females | Males | Females | Males | Females | | | Males | Females |
| AEC-1 | 8 | 10 | 9 | 3 | 22 | 16 | 0 | 68 | 6[s] | 1 |
| | 1 | 0 | 5 | 2 | 5 | 6 | 0 | 19 | 0 | 0 |
| AEC-2 | 7 | 1 | 9 | 3 | 15 | 9 | 1 | 45 | 6[s] | 0 |
| | 2 | 0 | 9 | 2 | 9 | 6 | 1 | 29 | 0 | 0 |
| AEC-3 | 1 | 0 | 1 | | 1[a] | | 0 | 3 | 1[s] | 0 |
| AEC-4 | 12 | 15 | 1 | 0 | 11 | 12 | 5 | 56 | 2[s] | 0 |
| | 0 | 2 | 0 | 0 | 5 | 4 | 2 | 13 | 0 | 0 |
| AEC-5 | 1[b] | 1[c] | 0 | 0 | 0 | 0 | 0 | (3) | 0 | 0 |
| | both males probably spent; female has decomposing pouch and contents | | | | | | | | | |
| AEC-6 | 8 | 1[d] | 2 | 3 | 4 | 12 | 0 | 30 | 7[s] | 0 |
| | 1 | 0 | 2 | 3[e] | 3 | 12(11[e]) | 0 | 18(14[e]) | 0 | 0 |
| AEC-7 | 26 | 9 | 8 | 7 | 27 | 14 | 4 | 95 | 20[s] | 0 |
| | 1 | 1 | 5 | 4 | 1 | 2 | 1 | 15 | 0 | 0 |

[a]telson of indeterminate sex; [b]plus one telson; [c]decomposition; [d]abdomen with pouch and egg mass attached; [e]normal-looking abdomens only; [s]with sperm extruding.

The numbers of recognizably spent individuals do not appear to be sufficient to account for the numbers of opaque white immotile specimens observed in the fresh collections.

Four types of morphological peculiarities that might be indicative of death before preservation were noted:

1. Eye cones and pigment receding from cuticle
2. Peculiar "rupture" of eye pigmentation and its migration down the eyestalks
3. Peculiar coloration, obviously rotted tissue, and empty stomachs (with or without 1 and 2 above)
4. Shrinkage of abdominal muscle away from cuticle wall

We have no evidence that these characteristics really distinguish individuals that were dead before preservation. The first, second, and fourth characteristics might be effects of the formalin preservative. The fourth might be due to partial dehydration of individuals adhering to the jar stopper or jar walls above the liquid preservative. Peculiar coloration, in these specimens at least, may be due to leachates from the phytoplankters with which they were stored for a few months. Decomposing tissue was found in only one specimen (the mature female from AEC-6). Empty stomachs were found in a few broken specimens, but we cannot be sure that the breakage might not have resulted in artificial emptying.

We are forced to conclude that the dead individuals (1) were for the most part so newly dead as to have no abnormal characteristics, and (2) died from causes at present unknown.

## PRELIMINARY OBSERVATIONS ON QUALITATIVE CHANGES IN THE PLANKTONIC DIATOM FLORA BETWEEN 1966 AND 1967

Changes in trophic status of natural waters are marked by concomitant changes in their fauna and flora. In some cases (Ninkow 1920; Minder 1923) eutrophication has been marked by the sudden appearance of a previously excluded organism or organisms. In most cases the changes have been more subtle and were not recognized until after they had taken place. It has been apparent for some time that diatom species characteristic of eutrophic habitats were gradually being introduced into the Lake Michigan flora (Skvortzow 1937; Baylis 1957; Vaughn 1961). It has been our experience that the majority of the introduced entities are abundant only in harbors and inshore waters that receive considerable and readily apparent nutrient loads.

In the early spring of 1967 this situation was rather dramatically reversed over the greater portion of the lake. Several species previously absent or rare in offshore plankton samples appeared in relatively high numbers, and the "usual" species composition of the spring plankton was substantially altered. Although not all the samples from the early spring cruises are as yet analyzed, the following three stations illustrate the trend present over a large portion of the lake. Table 7 gives the results.

Sample 913. Vertical #20 net haul, Station C-7. 20 March 1966.
Sample 1340. Vertical #20 net haul, Station C-7. 28 March 1967.
Sample 1351. Surface #20 net tow, entrance to harbor, Milwaukee, Wis., 21 April 1967.

In Table 7 the organisms are grouped by approximate trophic levels developed from extensive survey of the literature. Primary sources not specifically cited here were numerous papers by Hustedt and by Cholnoky in the years between 1922 and 1965. Remarks covering the majority of the species treated may be found in Huber-Pestalozzi (1942).

Study of Table 7 shows that although it is intermediate between the other two, the flora of Sample 1340 is qualitatively more similar to that of Milwaukee Harbor than to the flora that occurred at the same station on approximately the same date the previous year. Field observations and preliminary laboratory analyses indicate that similar situations obtained in all samples collected during March and April of 1967.

Our March and April samplings covered the southern two-thirds of the lake (north to the latitude of Frankfort, Mich.). It is to be inferred that the apparent changes affected most of Lake Michigan, and were not restricted to the southern end as were previously noted slight and progressive changes.

Although the import of these preliminary observations cannot be fully assessed at present, we tend to view them with a certain degree of alarm. The present data appear to indicate a spread of more eutrophied conditions into the main body of the lake.

## DISCUSSION

This paper was originally to be only a cataloging of a series of observed conditions which were deemed worthy of being called to the attention of the Great Lakes Research Community. That it is still a cataloging of observed conditions is obvious. That solid basic relationships have not been demonstrated is the reason that this section is headed "Discussion" instead of "Discussion and Conclusions." Originally it was not intended even to discuss the observations, but as the preparation of the paper progressed the authors became increasingly aware that all, or all but one, of the series of observations could possibly be manifestations of a lake-change phenomenon.

The literature cited in this paper shows that eutrophic plankters have been appearing in the Lake Michigan flora, among them the winter-spring blooming diatom associated with formation of calcium carbonate crystals in the water of the

TABLE 7. Percentage abundance of dominant phytoplankton diatoms at Station C-7 in March 1966 and 1967 and in the entrance to Milwaukee Harbor in April 1967.

| Organism | C-7<br>1966 | C-7<br>1967 | Milwaukee<br>1967 |
|---|---|---|---|
| ORGANISMS USUALLY OCCURRING IN OLIGOTROPHIC WATERS | | | |
| Melosira distans (Ehr.) Kütz. | 1.0 | -- | -- |
| Melosira islandica O. Müll. | 60.0 | 52.5 | 37.5 |
| Rhizosolenia eriense H. L. Smith | 1.0 | -- | -- |
| Stephanodiscus alpinus Hust. | 4.0 | 1.0 | X |
| Synedra ulna var. chaseana Thomas | 3.5 | X | X |
| ORGANISMS USUALLY OCCURRING IN MESOTROPHIC-OLIGOTROPHIC WATERS | | | |
| Cyclotella comta (Ehr.) Kütz. | -- | -- | X |
| ORGANISMS USUALLY OCCURRING IN MESOTROPHIC WATERS | | | |
| Synedra delicatissma Wm. Smith | -- | 2.5 | 2.0 |
| Synedra radians Kütz. | -- | X | 2.5 |
| ORGANISMS USUALLY OCCURRING IN EUTROPHIC WATERS | | | |
| Diatora tenue var. elongatum Lyngb. | -- | 5.5 | 11.0 |
| Fragilaria capucina Desm. | -- | X | X |
| Melosira binderana Kütz. | -- | 7.5 | 30.0 |
| Stephanodiscus astaea var. minutula (Kütz.) Grun. | 2.0 | X | -- |
| Stephanodiscus hantzschii Grun. | -- | X | 3.0 |
| ORGANISMS OCCURRING OVER A WIDE RANGE OF ECOLOGIC CONDITIONS | | | |
| Asterionella formosa Hassall | -- | 9.0 | 5.0 |
| Cyclotella kützingiana Thw. | 2.5 | X | -- |
| Cyclotella stelligera Grun. in Cl. and Grun. | X | -- | X |
| Fragilaria crotonensis Kitton | 5.0 | 3.5 | 2.5 |
| Fragilaria pinnata Ehr. | X | -- | -- |

TABLE 7. (Concluded)

| Organism | C-7<br>1966 | C-7<br>1967 | Milwaukee<br>1967 |
|---|---|---|---|
| *Nitzschia dissipata* (Kütz.) Grun. | -- | 1.5 | -- |
| *Nitzschia recta* Hantz. | -- | X | -- |
| *Tabellaria fenestrata* (Lyngb.) Kütz. | 10.5 | 6.5 | 3.5 |
| *Tabellaria flocculosa* (Roth) Kütz. | 1.0 | 1.5 | X |
| ORGANISMS WHOSE PRIMARY HABITAT IS NOT IN THE PLANKTON | | | |
| *Amphiprora ornata* Bailey | -- | -- | X |
| *Cymatopleura solea* var. *Apiculata* (Wm. Smith) Ralfs | -- | X | X |
| *Diatoma vulgare* Bory | -- | -- | X |
| *Navicula cryptocephala* var. *intermedia* Grun. | -- | -- | X |
| *Navicula tripunctata* (Müll.) Bory | -- | -- | X |
| *Surirella angustata* Kütz. | -- | X | X |
| *Surirella ovata* Kütz. | -- | -- | X |
| ORGANISMS OF UNCERTAIN OR DISPUTED TROPHIC LEVEL | | | |
| *Asterionella gracillima* (Hantz.) Heiberg | -- | -- | X |
| *Cyclotella michiganiana* Skv. | X | -- | -- |
| *Fragilaria intermedia* Grun. | 2.5 | 1.0 | X |
| *Nitzschia baccata* Hust. (?) | -- | -- | X |
| *Nitzschia lauenburgiana* Hust. | X | 2.0 | 1.0 |
| *Stephanodiscus niagarae* Ehr. | X | X | X |
| *Stephanodiscus transilvanicus* Pant. | 3.0 | X | X |
| *Synedra ulna* var. *danica* (Kütz.) V. H. | 4.0 | 5.0 | 1.0 |

-- = Organism not noted in sample.

X = Organism present at less than 1% of population.

Chicago area. The lakeward extension of this diatom and others characteristic of fertilized harbors in the spring of 1967 is also shown in this paper. In another paper in this volume Ayers and Strong show a tendency for recent summers to have had warmer and shallower epilimnia than in the past. Stoermer in other papers in this volume shows the present phytoplankton to be more eutrophic in composition than in the past.

The winter-spring blooming diatoms (associated with calcium carbonate crystals) that were discovered at Chicago, but which appeared in the open lake in the spring of 1967, could possibly be the cause of the milky water observed off Chicago in March of that spring. After spring, it appears that the warmer epilimnia could be stimulating other eutrophic phytoplankters to greater metabolic activity. This, in conjunction with the lessened dissolved free carbon dioxide in warmer epilimnetic water, may be causing the phytoplankters to draw upon calcium bicarbonate for their needed $CO_2$ with resultant precipitation of calcium carbonate. While not yet proven, the above combination appears capable of causing the marl-like milky water-color condition that has been observed in spring and summer.

Suspended and/or slowly sinking particles of calcium carbonate could both reflect white light to cause the milky-water appearance and scatter light that would otherwise have penetrated into the epilimnion to allow some degree of photosynthesis there. In other words, milky water could raise the compensation depth and diminish whatever hypolimnetic generation of oxygen might normally occur. The continued oxygen demand of the organic rain from the euphotic layer and the continuing oxygen demand of the organic fractions on and in the surficial bottom sediment could well have resulted in lower oxygen content and lower saturation levels as were observed in near-bottom water between 1954-55 and the present. It should be mentioned here that 1954-55 was apparently also a time of milky water and that the oxygen diminutions demonstrable may be conservative.

Whether or not the late-summer presence of dead adult or near-adult *Mysis* fits into this hypothesis is a moot point. Failures to collect them in the past may have been due to chance (absence of suitable collections and collecting gear at the right time). This seems unlikely; between our own and the U.S. Bureau of Commercial Fisheries' cruises, suitable gear and observers were in the field. Failure to notice dead mysids collected is a real possibility, of which we ourselves were guilty. Failure to obtain records of dead mysids may possibly be due to the fact that they had not died in such quantities before. To entertain this possibility leads to speculation that post-spawning debilitation, or a difficult pre-adult moult, may involve an unknown oxygen-level sensitivity that passed a critical level in 1966.

In summary, we have come to believe that the several sorts of observations above are all, or all but the *Mysis* die-off, related in some way. We note than an hypothesis involving epilimnetic precipitation of particulate calcium carbonate provides an adequate framework to make all the observed conditions (possibly excepting the Mysis die-off) fit together. The necessary measurements to test the validity of such an hypothesis are being activated.

## REFERENCES

BAYLIS, J. R. 1957. Micro-organisms that have caused trouble in the Chicago water system. Pure Water, 9(3): 45-49.

BEETON, A. M., and J. W. MOFFETT. 1964. Lake Michigan chemical data, 1954-55, 1960-61. Data Report 6, Fish and Wildlife Service, Bureau of Commercial Fisheries, U. S. Dept. of Interior. 100 p.

HUBER-PESTALOZZI, G. 1942. Das Phytoplankton des Süsswassers. In.: A. Thienemann (ed.) Die Binnengewasser, Bd. 16, 2 Teil, 2 Halfte. E. Nägele, Stuttgart.

HUTCHINSON, G. E. 1957. A treatise on limnology. Vol. 1. Geography, physics, and chemistry. John Wiley and Sons, New York. 1015 p.

MINDER, L. 1923. Über biogene Entkalkung in Zürichsee. Verhandl. Int. Verein Limnol., 1(2): 20-32.

NIPKOW, F. 1920. Vorläufige Mitteilung über Untersuchungen des Schlammabsatzes in Zürichsee. Schwiez. Zeitschr. Hydrobiol., 1: 100-122.

SKVORTZOW, B. V. 1937. Diatoms from Lake Michigan. I. Amer. Midland Nat., 18(4): 652-658.

VAUGHN, J. C. 1961. Coagulation difficulties at the South District Filtration Plant. Pure Water, 13(3): 45-49.

# SOME PRELIMINARY OBSERVATIONS ON THE DEPTH DISTRIBUTION OF MACROBENTHOS IN LAKE MICHIGAN

Charles F. Powers and Wayne P. Alley

During the period from August 1964 to June 1966, approximately 1461 macrobenthos samples, representing 487 triplicates, were obtained with either a Ponar or Smith-McIntyre grab-sampler at 35 stations in Lake Michigan (see Fig. 1, Ayers, Stoermer and McWilliam, this report). These samples were processed according to the methodology described in the above reference, and the following categories of information were obtained: numbers per square meter of amphipods, oligochaetes, sphaeriids, tendipedids, and total organisms; oven-dry weight of total organisms per square meter; and ash-free weight of total organisms per square meter.

Amphipods, oligochaetes, sphaeriids, and tendipedids constituted practically the entire macrobenthic biomass. A few taxonomic groups, such as mysids, roundworms, flatworms, and leeches, were only occasionally represented in our samples and are not considered in this report. Observations recently made from the research submarine STAR II during "Operation Submich" have shown that mysids are extremely plentiful in the deeper parts of the lake. They are, however, only slightly vulnerable to capture by grab-sampling devices. At present there seems to be no good way to sample these organisms on a reliable quantitative basis. Therefore, although the authors are aware of the importance of mysids in the benthic community, it has been necessary to eliminate them from consideration in the present study.

Computations from the IBM 7090 computer, in the form of graphical printouts, have been utilized here for a presentation of some distributional features of the macrobenthos. The average values of the macrobenthos data obtained at each station visit during the sampling period were plotted with respect to depth and appear as Figs. 1-7. Approximately 487 points are represented in each graph. However, when the computer prints out graphical results it rounds off numbers to significant places and thus many calculated points are represented as a single point.

Figures 1-7 represent the range of average values found at each depth increment. It is readily observable that a greater range of average values exists in shallower depths. This greater variability of values probably reflects the greater environmental variability of the more shallow regions.

The data from each of these macrobenthic categories were also pooled into 10-m depth increments. The shallowest depth increment included all observations between 6 and 15 m and is designated the 10-m increment; the next depth increment includes all observations between 16 and 25 and is the 20-m increment, and so forth. The numbers of samples occurring at each depth increment, the standard deviations, and the means are given in Tables 1-7. These means were plotted against their respective depths and appear as Figs. 8-14.

A basic similarity among the seven categories is readily evident from these graphs. In all categories there is a concentration zone between 20 and 60 m, beyond which there is a more or less regular decrease with depth. The exceptions to this pattern are the high values shown for the 10-m increment by sphaeriids, oligochaetes, total organisms, dry weight, and ash-free weight. This depth increment is represented almost entirely by a single station, B-8, located near the Waukegan Harbor entrance, which may not necessarily be representative of the 10-m depth zone.

Maximum numbers of amphipods occur at a depth of approximately 30 m with a minor peak at 120 m. The relationships of oligochaetes and sphaeriids with depth are similar in that they both have large numbers at 10 m, show a decline at 20 m, an increase at 30 m, and finally progressively decrease in numbers at greater depths. The decrease in sphaeriids is very rapid between 50 and 120 m, beyond which depth the numbers are uniformly quite low. Oligochaetes show a rapid decrease between 50 and 80 m, tend to level off until 170 m, and then decrease further beyond 180 m. Tendipedids show maximum numbers at 40 to 50 m with minor peaks occurring at 70 and 100 m.

Amphipods are, by a large margin, the most abundant benthic organism, followed by oligochaetes, sphaeriids, and tendipedids, in that order. The overall average numbers of these groups, and the percentage each contributes to the total counts, are as follows:

| Group | Grand Avg. Number/m$^2$ | Percent of Total |
|---|---|---|
| Amphipods | 2736 | 64 |
| Oligochaetes | 853 | 20 |
| Sphaeriids | 642 | 15 |
| Tendipedids | 52 | 1 |

Dry weight and ash-free weight both exhibit increased values in the 10-m depth zone, as previously indicated. The increase is particularly evident in dry weight, where values approaching 25 gm/m$^2$ are found. This appears to be directly attributable to the shell weights of the numerous large sphaeriids found at station B-8. Beyond the 10-m increment high values for dry and ash-free weights occur between 30 and 50 m, after which there is a gradual decline to very low values in the greatest depths.

The grand average dry weight of macrobenthos was 3.6 gm/m$^2$, or 36 kg per hectare. The corresponding grand average ash-free weight was 2.3 gm/m$^2$, or 23 kg per hectare. Ash-free weight, then, is on an overall basis, equal to about two-thirds of the dry weight of the macrobenthos before ashing.

It is apparent from these data that the macrobenthic organisms are inversely related to depth. However, this does not imply that depth alone is the only factor that influences the density distribution of these organisms; depth merely represents one component of a complex system that regulates the abundance of all aquatic organisms. In subsequent analysis the authors intend to investigate the interrelationships of the density distributions of these macrobenthic organisms with such environmental components as bottom temperature, sediment type, carbon content, suspended particulate matter, organic content of the zooplankton, and the interaction of these macrobenthic taxonomic groups in order to gain a better prospective of the benthic community.

TABLE 1. Calculated results of pooled data for amphipods/m$^2$.

| Depth Meters | No. of Samples | Standard Deviation | Mean |
|---|---|---|---|
| 10.0 | 46 | 3099 | 3822 |
| 20.0 | 142 | 3660 | 4015 |
| 30.0 | 144 | 3726 | 8588 |
| 40.0 | 186 | 3094 | 6850 |
| 50.0 | 131 | 2804 | 6343 |
| 60.0 | 41 | 1135 | 3935 |
| 70.0 | 87 | 1246 | 3910 |
| 80.0 | 89 | 1342 | 3592 |
| 90.0 | 57 | 1639 | 3515 |
| 100.0 | 102 | 1522 | 3146 |
| 110.0 | 42 | 997 | 2490 |
| 120.0 | 47 | 1056 | 3270 |
| 130.0 | 69 | 1047 | 2380 |
| 140.0 | 12 | 918 | 1758 |
| 150.0 | 15 | 529 | 2270 |
| 160.0 | 36 | 1173 | 2071 |
| 170.0 | 63 | 756 | 1749 |
| 180.0 | 12 | 1263 | 1495 |
| 190.0 | 6 | 366 | 1104 |
| 200.0 | 41 | 764 | 1274 |
| 210.0 | 15 | 465 | 772 |
| 220.0 | 8 | 225 | 714 |
| 230.0 | 3 | 310 | 366 |
| 240.0 | 5 | 259 | 546 |
| 260.0 | 20 | 358 | 489 |
| 270.0 | 15 | 384 | 659 |

TABLE 2. Calculated results of pooled data for oligochaetes/m$^2$.

| Depth Meters | No. of Samples | Standard Deviation | Mean |
|---|---|---|---|
| 10.0 | 40 | 5808 | 6057 |
| 20.0 | 140 | 2995 | 1634 |
| 30.0 | 135 | 2768 | 2500 |
| 40.0 | 183 | 1737 | 2199 |
| 50.0 | 127 | 2566 | 2240 |
| 60.0 | 39 | 850 | 1384 |
| 70.0 | 85 | 1026 | 847 |
| 80.0 | 89 | 450 | 587 |
| 90.0 | 51 | 509 | 657 |
| 100.0 | 108 | 532 | 502 |
| 110.0 | 42 | 278 | 424 |
| 120.0 | 38 | 223 | 284 |
| 130.0 | 66 | 394 | 449 |
| 140.0 | 9 | 341 | 496 |
| 150.0 | 15 | 425 | 547 |
| 160.0 | 33 | 393 | 382 |
| 170.0 | 62 | 831 | 368 |
| 180.0 | 9 | 98 | 93 |
| 190.0 | 6 | 66 | 93 |
| 200.0 | 38 | 224 | 227 |
| 210.0 | 15 | 22 | 6 |
| 220.0 | 8 | 10 | 12 |
| 230.0 | 3 | 0 | 0 |
| 240.0 | 5 | 65 | 47 |
| 260.0 | 20 | 103 | 55 |
| 270.0 | 15 | 82 | 93 |

TABLE 3. Calculated results of pooled data for sphaeriids/$m^2$.

| Depth Meters | No. of Samples | Standard Deviation | Mean |
|---|---|---|---|
| 10.0 | 46 | 2553 | 3126 |
| 20.0 | 143 | 1172 | 898 |
| 30.0 | 144 | 3463 | 3906 |
| 40.0 | 186 | 1752 | 2409 |
| 50.0 | 131 | 1776 | 2460 |
| 60.0 | 42 | 883 | 1243 |
| 70.0 | 88 | 555 | 730 |
| 80.0 | 89 | 341 | 422 |
| 90.0 | 57 | 282 | 354 |
| 100.0 | 102 | 238 | 295 |
| 110.0 | 42 | 144 | 201 |
| 120.0 | 47 | 103 | 116 |
| 130.0 | 69 | 73 | 63 |
| 140.0 | 12 | 39 | 30 |
| 150.0 | 15 | 41 | 43 |
| 160.0 | 36 | 68 | 66 |
| 170.0 | 65 | 110 | 72 |
| 180.0 | 12 | 69 | 36 |
| 190.0 | 6 | 62 | 57 |
| 200.0 | 41 | 76 | 47 |
| 210.0 | 15 | 70 | 32 |
| 220.0 | 8 | 64 | 43 |
| 230.0 | 3 | 12 | 7 |
| 240.0 | 5 | 30 | 22 |
| 260.0 | 20 | 19 | 10 |
| 270.0 | 15 | 17 | 5 |

TABLE 4. Calculated results of pooled data for tendipedids/$m^2$.

| Depth Meters | No. of Samples | Standard Deviation | Mean |
|---|---|---|---|
| 10.0 | 46 | 58 | 59 |
| 20.0 | 143 | 119 | 68 |
| 30.0 | 144 | 158 | 126 |
| 40.0 | 186 | 354 | 182 |
| 50.0 | 131 | 270 | 203 |
| 60.0 | 42 | 155 | 103 |
| 70.0 | 88 | 231 | 136 |
| 80.0 | 89 | 103 | 79 |
| 90.0 | 57 | 65 | 40 |
| 100.0 | 102 | 124 | 95 |
| 110.0 | 42 | 62 | 59 |
| 120.0 | 47 | 42 | 29 |
| 130.0 | 69 | 43 | 22 |
| 140.0 | 12 | 18 | 27 |
| 150.0 | 15 | 70 | 39 |
| 160.0 | 36 | 34 | 27 |
| 170.0 | 65 | 35 | 22 |
| 180.0 | 12 | 5 | 1 |
| 190.0 | 6 | 18 | 7 |
| 200.0 | 41 | 17 | 9 |
| 210.0 | 15 | 8 | 4 |
| 220.0 | 8 | 16 | 8 |
| 230.0 | 3 | 0 | 0 |
| 240.0 | 5 | 19 | 9 |
| 260.0 | 20 | 7 | 3 |
| 270.0 | 15 | 4 | 1 |

TABLE 5. Calculated results of pooled data for total counts of macrobenthos/$m^2$.

| Depth Meters | No. of Samples | Standard Deviation | Mean |
|---|---|---|---|
| 10.0 | 40 | 9723 | 13816 |
| 20.0 | 140 | 6313 | 6543 |
| 30.0 | 138 | 6747 | 15012 |
| 40.0 | 177 | 4533 | 11483 |
| 50.0 | 127 | 5086 | 11175 |
| 60.0 | 39 | 2557 | 6691 |
| 70.0 | 85 | 2281 | 5575 |
| 80.0 | 89 | 1790 | 4682 |
| 90.0 | 57 | 2114 | 4574 |
| 100.0 | 102 | 1998 | 4034 |
| 110.0 | 42 | 1217 | 3174 |
| 120.0 | 38 | 1216 | 3811 |
| 130.0 | 66 | 1282 | 2981 |
| 140.0 | 9 | 1128 | 2381 |
| 150.0 | 15 | 910 | 2899 |
| 160.0 | 33 | 1341 | 2662 |
| 170.0 | 62 | 1425 | 2183 |
| 180.0 | 9 | 1277 | 1968 |
| 190.0 | 6 | 381 | 1261 |
| 200.0 | 38 | 939 | 1617 |
| 210.0 | 15 | 516 | 813 |
| 220.0 | 8 | 181 | 777 |
| 230.0 | 3 | 307 | 373 |
| 240.0 | 5 | 353 | 624 |
| 260.0 | 20 | 371 | 557 |
| 270.0 | 15 | 424 | 763 |

TABLE 6. Calculated results of pooled data for dry weight of macrobenthos, mg/$m^2$.

| Depth Meters | No. of Samples | Standard Deviation | Mean |
|---|---|---|---|
| 10.0 | 46 | 20954 | 23533 |
| 20.0 | 142 | 7959 | 7260 |
| 30.0 | 144 | 4927 | 10301 |
| 40.0 | 183 | 3779 | 8620 |
| 50.0 | 131 | 3127 | 7576 |
| 60.0 | 42 | 1807 | 4595 |
| 70.0 | 88 | 1253 | 3531 |
| 80.0 | 89 | 1195 | 3166 |
| 90.0 | 57 | 1530 | 3303 |
| 100.0 | 102 | 1538 | 2974 |
| 110.0 | 42 | 854 | 2433 |
| 120.0 | 51 | 740 | 2518 |
| 130.0 | 69 | 932 | 2018 |
| 140.0 | 9 | 1018 | 1803 |
| 150.0 | 15 | 675 | 2053 |
| 160.0 | 36 | 846 | 1586 |
| 170.0 | 65 | 665 | 1480 |
| 180.0 | 12 | 704 | 993 |
| 190.0 | 6 | 308 | 823 |
| 200.0 | 41 | 658 | 939 |
| 210.0 | 15 | 132 | 285 |
| 220.0 | 9 | 163 | 306 |
| 230.0 | 3 | 283 | 280 |
| 240.0 | 5 | 158 | 275 |
| 260.0 | 20 | 157 | 266 |
| 270.0 | 15 | 183 | 349 |

TABLE 7. Calculated results of pooled data for ash-free weight of macrobenthos, mg/m$^2$.

| Depth Meters | No. of Samples | Standard Deviation | Mean |
|---|---|---|---|
| 10.0 | 44 | 5796 | 7080 |
| 20.0 | 143 | 3378 | 3363 |
| 30.0 | 144 | 3073 | 7106 |
| 40.0 | 186 | 2874 | 6679 |
| 50.0 | 131 | 2314 | 5723 |
| 60.0 | 42 | 1295 | 3613 |
| 70.0 | 88 | 1024 | 2829 |
| 80.0 | 89 | 959 | 2571 |
| 90.0 | 57 | 1363 | 2774 |
| 100.0 | 102 | 1317 | 2510 |
| 110.0 | 42 | 742 | 2056 |
| 120.0 | 48 | 628 | 2229 |
| 130.0 | 72 | 828 | 1736 |
| 140.0 | 9 | 659 | 1274 |
| 150.0 | 15 | 548 | 1763 |
| 160.0 | 35 | 737 | 1349 |
| 170.0 | 68 | 537 | 1288 |
| 180.0 | 9 | 518 | 614 |
| 190.0 | 6 | 272 | 722 |
| 200.0 | 41 | 589 | 802 |
| 210.0 | 15 | 121 | 225 |
| 220.0 | 9 | 151 | 257 |
| 230.0 | 3 | 254 | 247 |
| 240.0 | 5 | 142 | 245 |
| 260.0 | 20 | 127 | 223 |
| 270.0 | 15 | 156 | 283 |

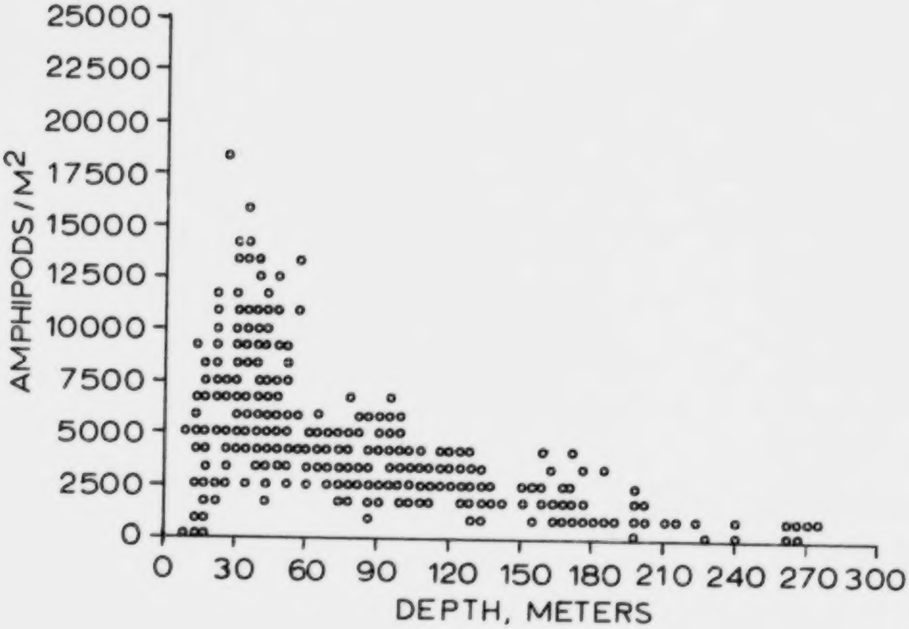


FIG. 1. Average numbers of amphipods/m$^2$ obtained at each station visit vs. depth in meters.

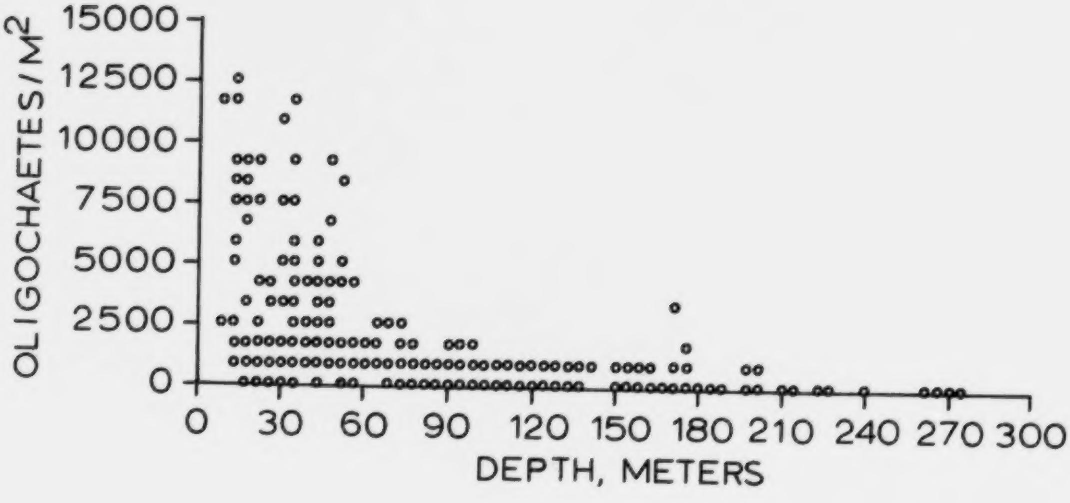


FIG. 2. Average numbers of oligochaetes/m$^2$ obtained at each station visit vs. depth in meters.

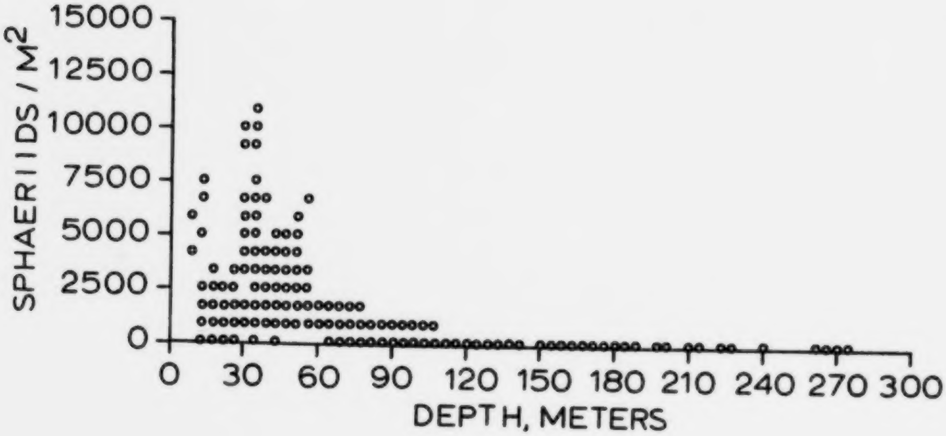


FIG. 3. Average numbers of sphaeriids/m$^2$ obtained at each station visit vs. depth in meters.

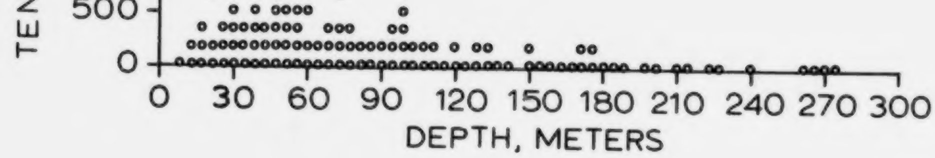


FIG. 4. Average numbers of tendipedids/m$^2$ obtained at each station visit vs. depth in meters.

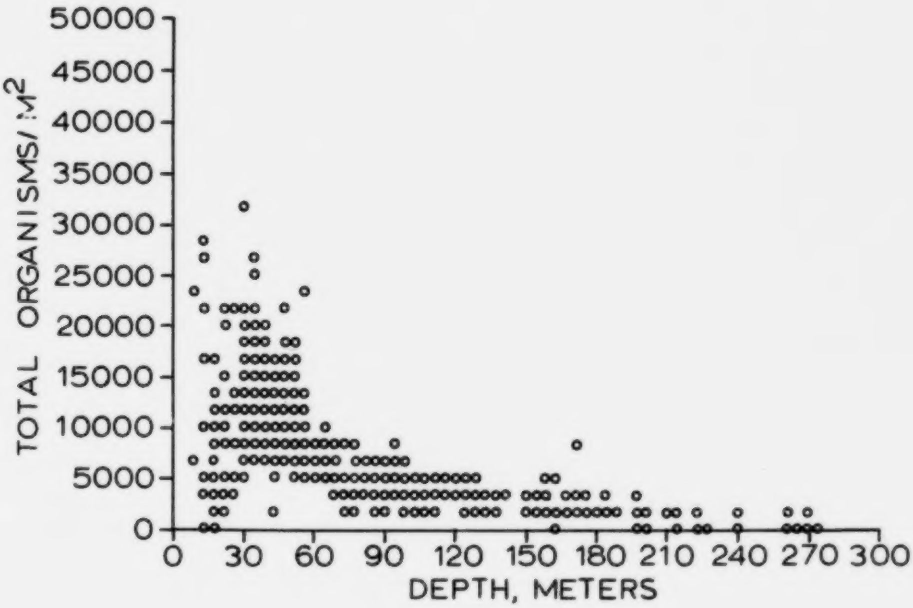


FIG. 5. Average numbers of total organisms/m$^2$ obtained at each station visit vs. depth in meters.

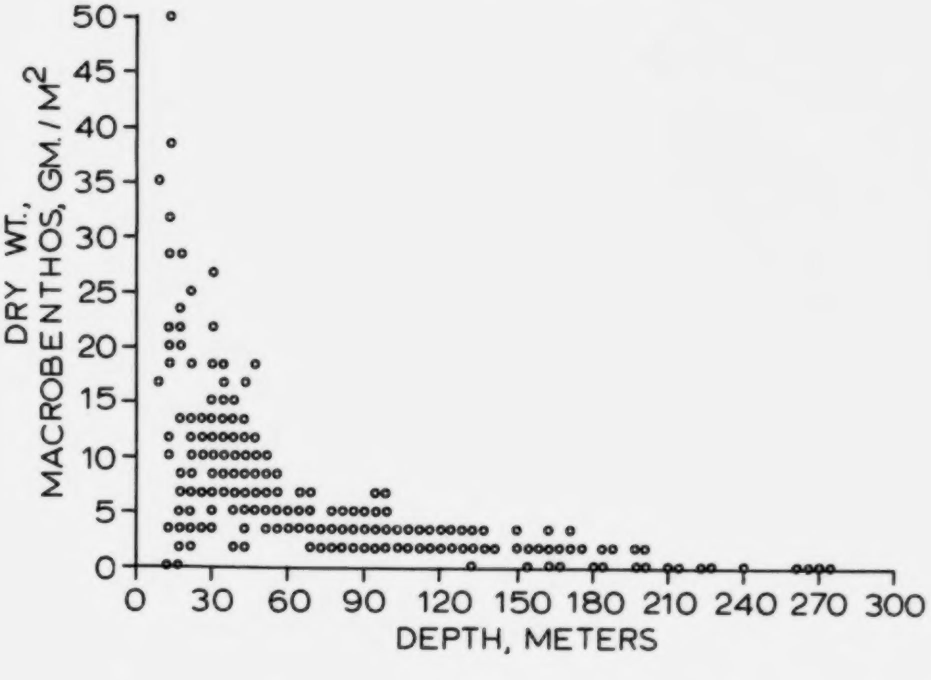


FIG. 6. Average dry weight of macrobenthos, gm/m$^2$ obtained at each station visit vs. depth in meters.

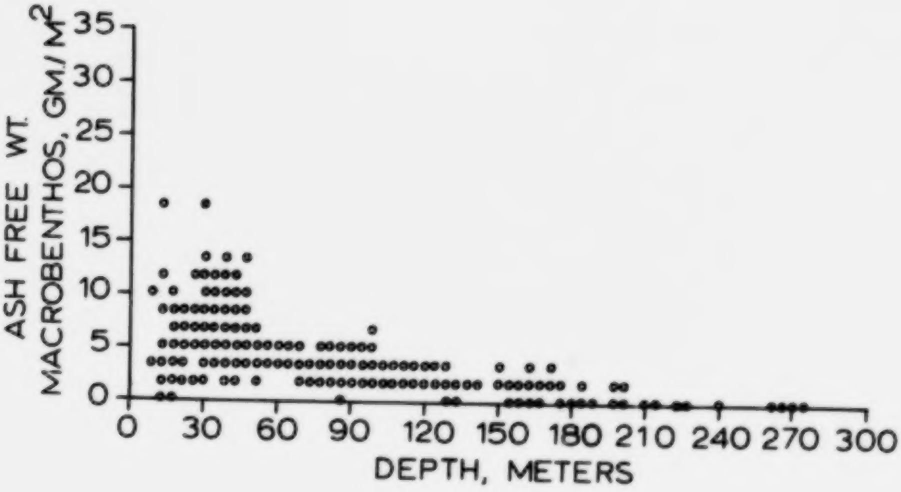


FIG. 7. Average ash-free weight of macrobenthos, gm/m$^2$ obtained at each station visit vs. depth in meters.

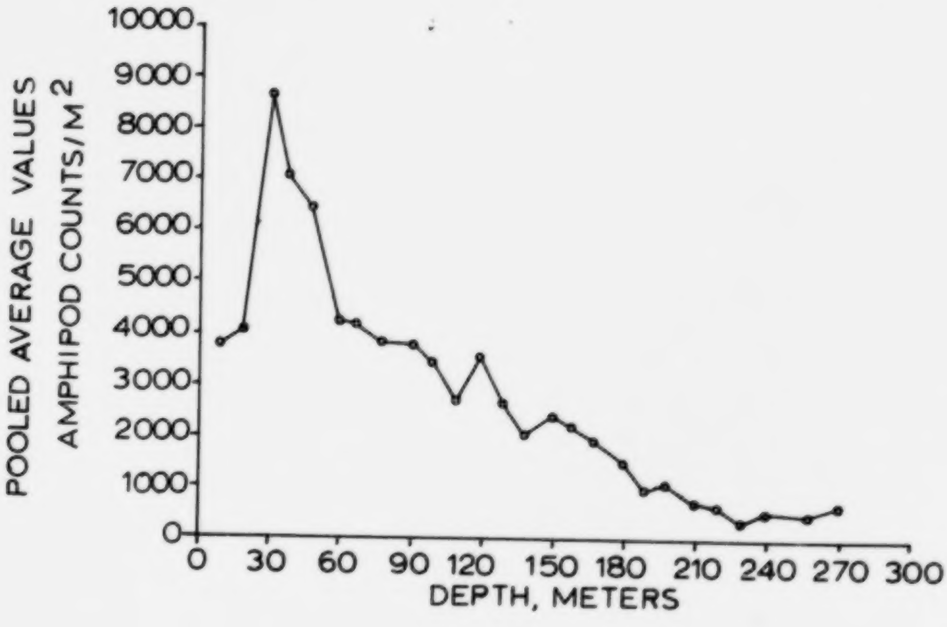


FIG. 8. Average numbers of amphipods/m$^2$ pooled by 10-m depth increments vs. depth in meters.

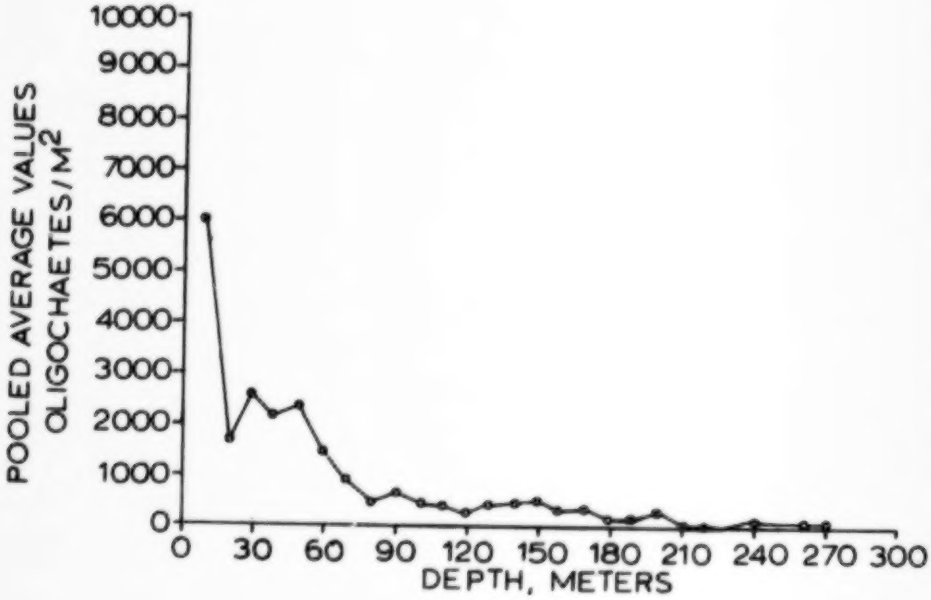


FIG. 9. Average numbers of oligochaetes/m$^2$ pooled by 10-m depth increments vs. depth in meters.

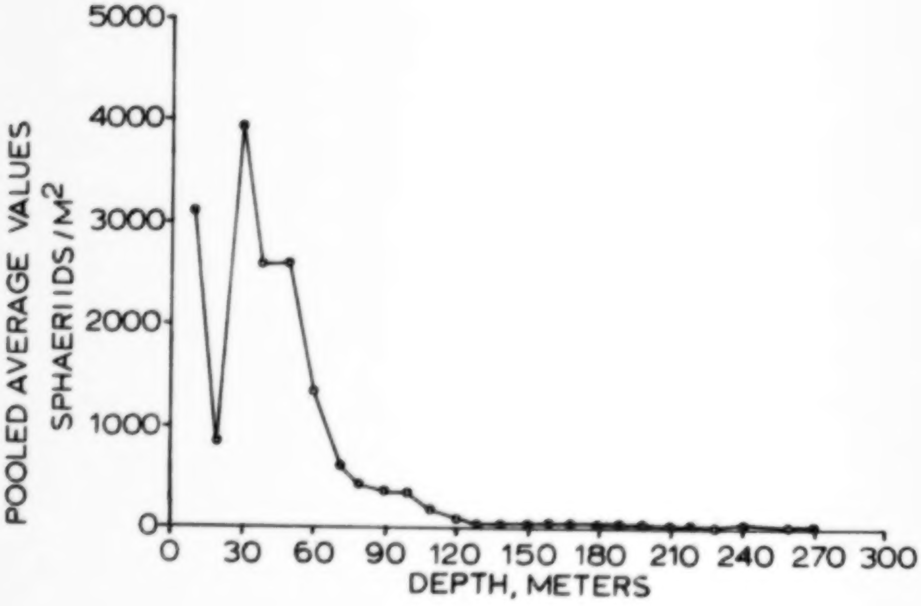


FIG. 10. Average numbers of sphaeriids/m$^2$ pooled by 10-m depth increments vs. depth in meters.

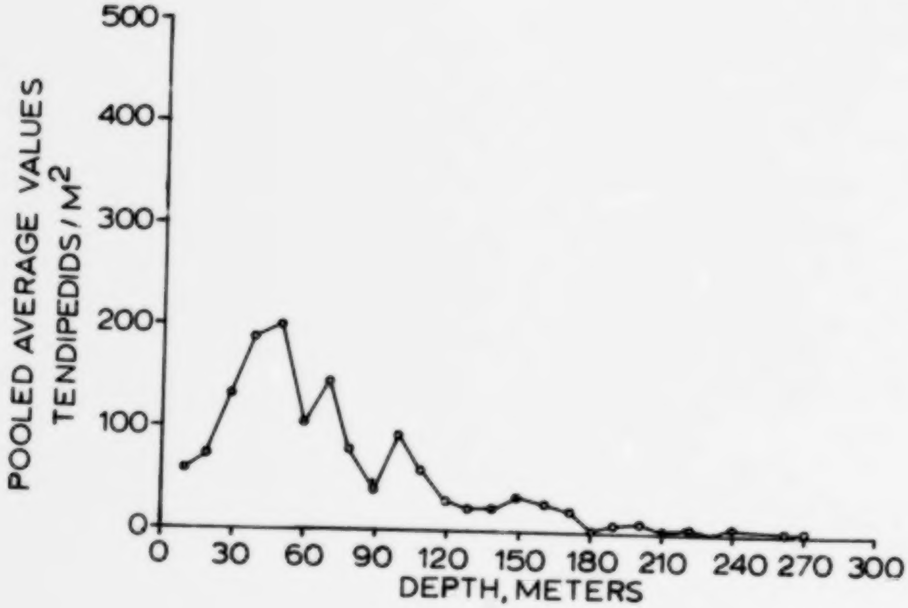


FIG. 11. Average numbers of tendipedids/$m^2$ pooled by 10-m depth increments vs. depth in meters.

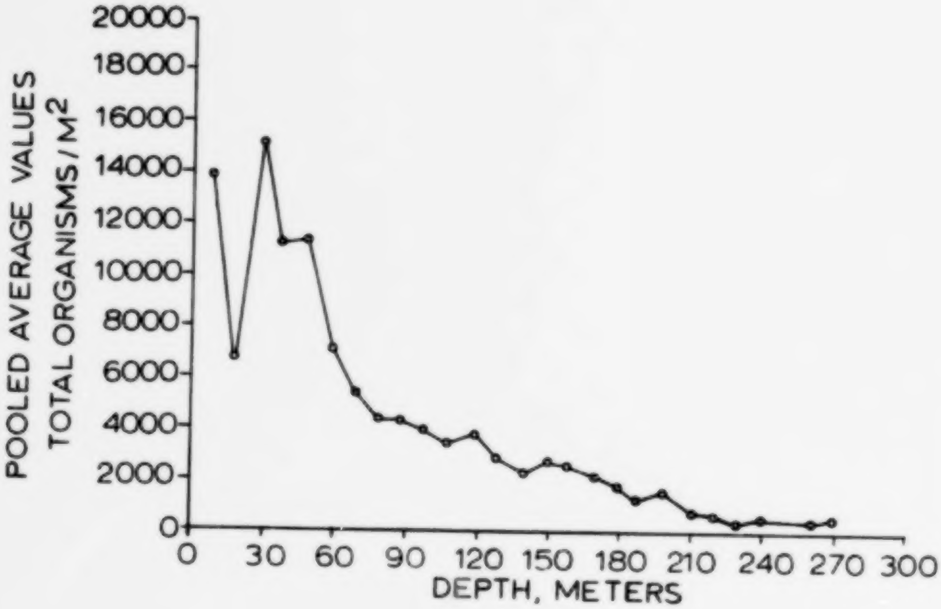


FIG. 12. Average numbers of total organisms/$m^2$ pooled by 10-m depth increments vs. depth in meters.

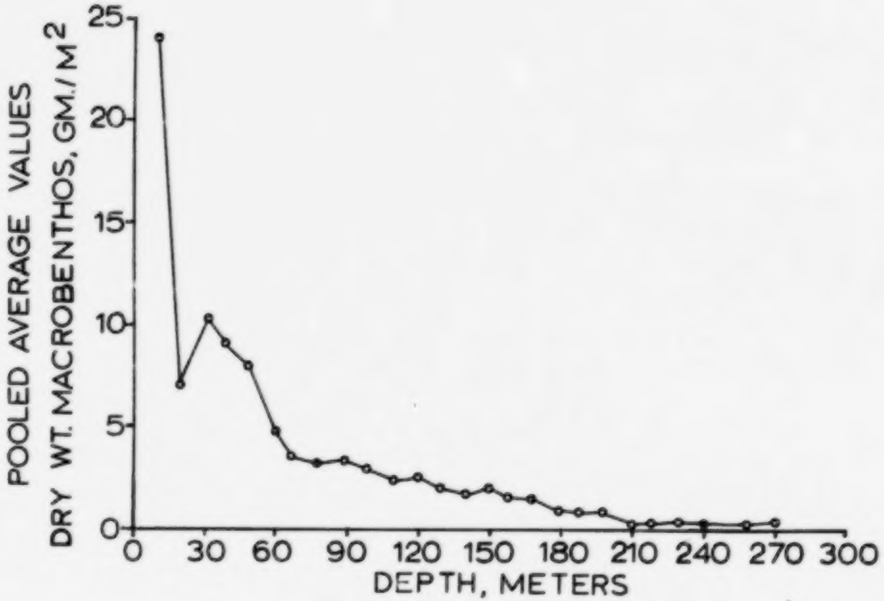


FIG. 13. Average dry weight of macrobenthos, gm/m$^2$ pooled by 10-m depth increments vs. depth in meters.

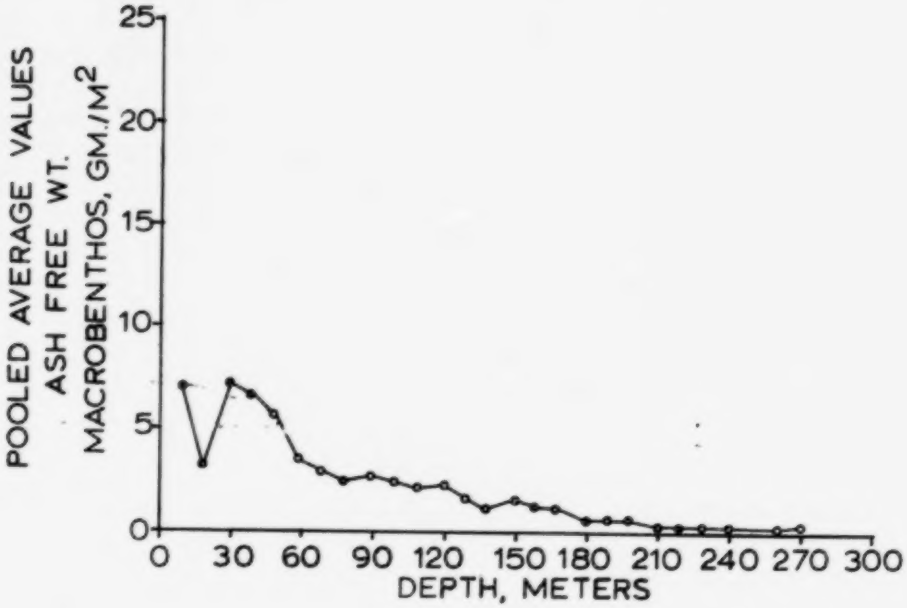


FIG. 14. Average ash-free weight of macrobenthos, gm/m$^2$ pooled by 10-m depth increments vs. depth in meters.

# DESIGN AND EVALUATION OF AN ALL-PURPOSE BENTHOS SAMPLER

Charles F. Powers and Andrew Robertson

Past attempts to sample quantitatively the macrobenthos of the Great Lakes have involved the use of a number of different kinds of grab samplers. The Foerst Petersen, orange peel, and Ekman grabs (Hopkins 1964) have been widely used, but little attention has been given to their actual sampling capabilities. Several years ago a modified version of the Petersen, the Franklin-Anderson dredge, was also introduced on the Great Lakes (Franklin and Anderson 1961). Recently Beeton, Carr and Hiltunen (1965) carried out studies on Lake Michigan in which the sampling efficiencies of the orange peel, Petersen, and Smith-McIntyre (McIntyre 1954; Hopkins 1964) samplers were compared. They found the efficiency of the Smith-McIntyre, based on the number of organisms captured per unit area of lake bottom, to be consistently higher than that of either the orange peel or the Petersen.

We have subsequently carried out similar tests in which the Petersen and Smith-McIntyre were compared at a series of stations in southern Lake Michigan. Triplicate samples were taken with each instrument at each of a series of stations between Holland, Mich., and Racine, Wis. on two different days. Depths ranged from 17 to 160 m. Sediment types at the stations included sand, silty sand, silt over firm clay, and very soft, soupy silt and clayey silt, so that a variety of firm and soft sediments were sampled. The macrobenthos from each of these samples was sorted into major taxonomic groups and the number of organisms in each group counted. The total number of all organisms was also obtained. The mean number of amphipods, oligochaetes, sphaeriids, and total organisms was obtained for each sampler at each station, and the ratios of number of organisms taken by the Petersen to number of organisms taken by the Smith-McIntyre calculated for each group at each station. The results are shown in Table 1. It is clear that, in general, the Smith-McIntyre captured more organisms of all kinds, at all depths and in all sediment types, than did the Petersen. In only four cases did the ratio exceed 1.00 (Petersen captured more organisms than the Smith-McIntyre) and in two of those cases the number of organisms taken by both instruments was so small (less than 10) as to probably make the results nonsignificant. The average ratio, Petersen/Smith-McIntyre, for total number of organisms caught at all stations is 0.41.

As a result of these comparative studies, we adopted the Smith-McIntyre grab for quantitative studies of the macrobenthos in the Great Lakes. However, the instrument was not satisfactory from various operational aspects. It is large and unwieldy, the mechanism is complicated and subject to failure, and the powerful tripping springs render it somewhat dangerous. Accordingly, we set out to design a sampler which would be at least as efficient as the Smith-McIntyre and yet be safe and easy to use. Such a sampler, named the Ponar, has been developed (Figs. 1 and 2). It has the quarter-cylinder jaw design of the Smith-McIntyre, including the screened top to reduce shockwave, and a closing mechanism modified from that of the Petersen. End plates prevent the escape of sediment and organisms until the jaws close.

The sampling efficiency of this new grab was compared to that of the Smith-McIntyre. Triplicate samples were taken with each instrument at the same series of stations (with the exception of two on the west side of the lake) at which our comparisons of the Petersen and Smith-McIntyre were carried out. Macrobenthos was sorted and enumerated and mean numbers obtained after the procedure followed in the previous comparative studies. The ratios of Smith-McIntyre to Ponar results for these different parameters at each station (Table 2) show that the Ponar is at least as efficient as the Smith-McIntyre. The average ratio, Smith-McIntyre/Ponar, for total number of organisms caught at all stations is 0.77.

The new sampler has also been tested in several smaller bodies of water in Michigan where it was compared to the Ekman and the Petersen bottom samplers. Three samples were taken with each instrument at each station and the organisms counted as described previously. The total number of organisms in each sample was calculated and is presented in Table 3. Only the Ekman and Ponar were used at the two stations in Whitmore Lake. One sample with the Petersen in Lake Charlevoix was lost and the Ekman could be made to sample only twice at the first station in Muskegon Lake.

Too few samples have been obtained as yet to draw any final conclusions from these latter studies. However, the counts indicate that the Ponar is a better all-purpose bottom sampler than either of the others. The three Ekman samples have lower counts than any obtained from either the Ponar or the Petersen samples at the Grand River and the Lake Charlevoix stations. The bottoms at these stations were hard sand and marl, respectively, and it is suggested that the relatively light Ekman did not bite deeply enough into these bottoms to take a satisfactory sample. On the other hand, at the two stations in Muskegon Lake the Ekman appears satisfactory, but the Petersen results are generally lower than those from the other two samplers. There the bottom was soft, and it is likely that under such conditions some organisms and sediment are flushed out between the jaws as the sampler strikes bottom.

## ACKNOWLEDGMENTS

It should be pointed out that three persons, in addition to the authors, contributed strongly to the development of the Ponar grab sampler. Vincent E. Noble and John C. Ayers participated in the design and field testing of the instrument, and Robert A. Ogle, Jr., assisted in both the design and fabrication of the pilot model. The name of the instrument derives from a combination of the initials of Powers, Ogle, Noble, Ayers, and Robertson.

## REFERENCES

BEETON, A. M., J. F. CARR, and J. K. HILTUNEN. 1965. Sampling efficiencies of three kinds of dredges in southern Lake Michigan. Univ. of Mich., Great Lakes Research Div., Pub. 13, p. 209 (abs.).

FRANKLIN, W. R., and D. V. ANDERSON. 1961. A bottom sediment sampler. Limnol. and Oceanog., 6(2): 233-234.

HOPKINS, T. L. 1964. A survey of marine bottom samplers. In Progress in Oceanography, Vol. 2, Mary Sears, Ed. The Macmillan Co., N. Y.

McINTYRE, A. D. 1954. A spring-loaded bottom sampler. J. Marine Biol. Assoc. U. K., 33: 257-264.

TABLE 1. Comparison of sampling efficiencies of Petersen and Smith-McIntyre grab samplers for amphipods (A), oligochaetes (O), sphaeriids (S), and total organisms (T) in Lake Michigan on two dates, 1964.

| Date | Depth (m) | Sediment Type | Petersen Result/ Smith-McIntyre Result | | | |
|---|---|---|---|---|---|---|
| | | | A | O | S | T |
| 17 June | 17 | Sand | 0.96 | 1.00 | 0.28 | 0.81 |
| | 49 | Silt-clayey silt | 0.28 | 0.27 | 0.07 | 0.24 |
| | 78 | Silt-clayey silt | 0.15 | 0.17 | -- | 0.14 |
| | 96 | Silt over firm plastic clay | 0.27 | 0.36 | 0.67 | 0.28 |
| | 152 | Silt-clayey silt | 0.13 | 0.20 | -- | 0.13 |
| | | Average | 0.36 | 0.40 | 0.34 | 0.32 |
| 27 July | 18 | Sand | 0.66 | 1.17 | 0.47 | 0.65 |
| | 46 | Silt-clayey silt | 0.70 | 0.56 | 0.49 | 0.61 |
| | 79 | Silt-clayey silt | 0.17 | 0.07 | 0.04 | 0.13 |
| | 60 | Silty sand | 0.68 | 2.75 | 1.75 | 0.87 |
| | 98 | Silt over firm plastic clay | 0.47 | 0.83 | 0.20 | 0.47 |
| | 108 | Silt over firm plastic clay | 0.33 | 0.75 | 0.25 | 0.32 |
| | 160 | Silt-clayey silt | 0.32 | 0.33 | -- | 0.31 |
| | | Average | 0.48 | 0.92 | 0.53 | 0.48 |

TABLE 2. Comparisons of sampling efficiencies of Ponar and Smith-McIntyre grab samplers for amphipods (A), oligochaetes (O), sphaeriids (S), and total organism (T) in Lake Michigan, April, 1965.

| Depth (m) | Sediment Type | Smith-McIntyre Result/Ponar Result | | | |
|---|---|---|---|---|---|
| | | A | O | S | T |
| 21 | Sand | 1.08 | 1.19 | 0.58 | 0.85 |
| 54 | Silt-clayey silt | 0.45 | 1.13 | 0.53 | 0.68 |
| 20 | Sand | 1.03 | 0.50 | 0.33 | 0.87 |
| 45 | Silt-clayey silt | 0.85 | 1.00 | 0.91 | 0.91 |
| 82 | Silt-clayey silt | 1.13 | 0.58 | 0.85 | 1.00 |
| 106 | Silt over firm plastic clay | 0.66 | 1.02 | 0.81 | 0.66 |
| 156 | Silt-clayey silt | 0.33 | 0.70 | 0.90 | 0.41 |

TABLE 3. Comparison of the total number of organisms caught by the Ponar (Po), Ekman (E), and Petersen (Pe) grab samplers in several environments.

| Location | Total No. of Organisms/m$^2$ | | |
|---|---|---|---|
| | Po | E | Pe |
| Muskegon L. #1 | 10,019 | 8,008 | 2,073 |
| | 7,288 | 17,534 | 987 |
| | 7,848 | -- | 1,114 |
| Muskegon L. #2 | 2,021 | 5,013 | 3,652 |
| | 3,376 | 5,533 | 2,200 |
| | 5,504 | 5,637 | 2,961 |
| Grand R. | 882 | 146 | 1,170 |
| | 2,021 | 437 | 677 |
| | 1,763 | 541 | 945 |
| L. Charlevoix | 753 | 374 | -- |
| | 667 | 354 | 465 |
| | 667 | 270 | 465 |
| Whitmore L. #1 | 1,118 | 2,496 | -- |
| | 1,967 | 3,037 | -- |
| | 1,698 | 749 | -- |
| Whitmore L. #2 | 387 | 83 | -- |
| | 602 | 166 | -- |
| | 258 | 374 | -- |

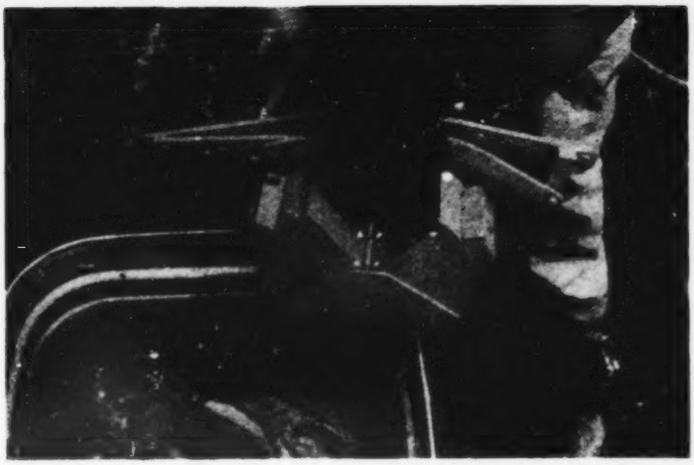


FIG. 1. Ponar grab sampler in open position, showing screened top, weights, side plates, and tripping mechanism.

FIG. 2. Ponar grab sampler in closed position, being brought on deck.

# A NOTE ON THE SPHAERIIDAE OF LAKE MICHIGAN

Andrew Robertson

As part of a general program on the biology of Lake Michigan, extensive studies have been conducted on the benthic environment (Powers and Robertson 1965, 1967; Robertson and Alley 1966; and Robertson and Powers 1967). During this work sphaeriids were commonly collected, and they form an important part of the benthic community of the lake. A small, representative part of these sphaeriids were sent to Rev. H. B. Herrington for identification, and this paper reports the results of his determinations. I would like to thank him here for making these identifications.

The sphaeriids of Lake Michigan have been studied previously by Baker (1930), Heard (1962a), and Henson and Herrington (1965). The present work is intended only as a supplement to these previous investigations in the hope that the results may provide useful additional information for future workers.

The stations from which the sphaeriids were collected and identified are shown in Fig. 1. The collections were made in August 1964 with a Smith-McIntyre grab sampler and were separated from most of the sediment through the use of the elutriation device described by Powers and Robertson (1965). The washed samples were preserved in buffered formalin and returned to the laboratory where the benthic organisms were sorted and enumerated. The sphaeriids were placed in alcohol and stored in small vials until identified. The systematics and nomenclature follows that of Herrington's (1962) revision of the Sphaeriidae of North America.

The number of each sphaeriid species found at each station is presented in Table 1. The values are in terms of organisms per sample, however, they can be converted to organisms per square meter by multiplying by 16.3.

Twelve species were found in these samples. Ten of them had been reported previously from Lake Michigan (Heard 1962a). Sphaerium corneum and Pisidium amnicum, however, are reported here for the first time from Lake Michigan. Heard (1962b) considered both of these species to have been introduced from Europe and to have advanced upstream in the St. Lawrence drainage only as far as Lakes Erie and Huron, respectively. It seems they have now extended their range to include Lake Michigan. The table shows that most of the species were restricted to the shallow-water stations. Only P. conventus was a true profundal species in Lake Michigan. It was not found in the four stations shallower than 29 m but was found to a depth of 200 m. However, its highest concentration fell off from there as depth increased. Except for one stray specimen of S. corneum, P. lilljeborgi was the only other species to extend into water over 30 m in depth.

In summary, it can be stated that species diversity of sphaeriids decreases with increasing depth in Lake Michigan. In the shallow, nearshort zone, to a depth of 20 to 30 m, a rather large number of species are present, but past this depth P. conventus is the predominant species and is the only sphaeriid present over the greater part of the bottom of the lake.

## REFERENCES

BAKER, F. C. 1930. The molluscan fauna of the southern part of Lake Michigan and its relationship to old glacial Lake Chicago. Trans. Ill. State Acad. Sci., 22: 186-194.

HEARD, W. H. 1962a. Distribution of Sphaeriidae (Pelecypoda) in Michigan. Malocologia, 1: 139-161.

__________. 1962. The Sphaeriidae (Mollusca: Pelecypoda) of the North American Great Lakes. Am. Midland Naturalist, 67: 194-198.

HENSON, E. B. and H. B. HERRINGTON. 1965. Sphaeriidae (Mollusca: Pelecypoda) of Lakes Huron and Michigan in the vicinity of the Straits of Mackinac. Proc. 8th Conf. on Great Lakes Res., p. 77-95.

HERRINGTON, H. B. 1962. A revision of the Sphaeriidae of North America (Mollusca: Pelecypoda). Misc. Pub., Mus. Zool., Univ. Mich., No. 118, 74 p.

POWERS, C. F. and A. ROBERTSON. 1965. Some quantitative aspects of the macrobenthos of Lake Michigan. Proc. 8th Conf. on Great Lakes Res., p. 153-159.

__________, and __________. 1967. Zonation of the benthic environment in Lake Michigan. Great Lakes Res. Div., Univ. Mich. (In this report).

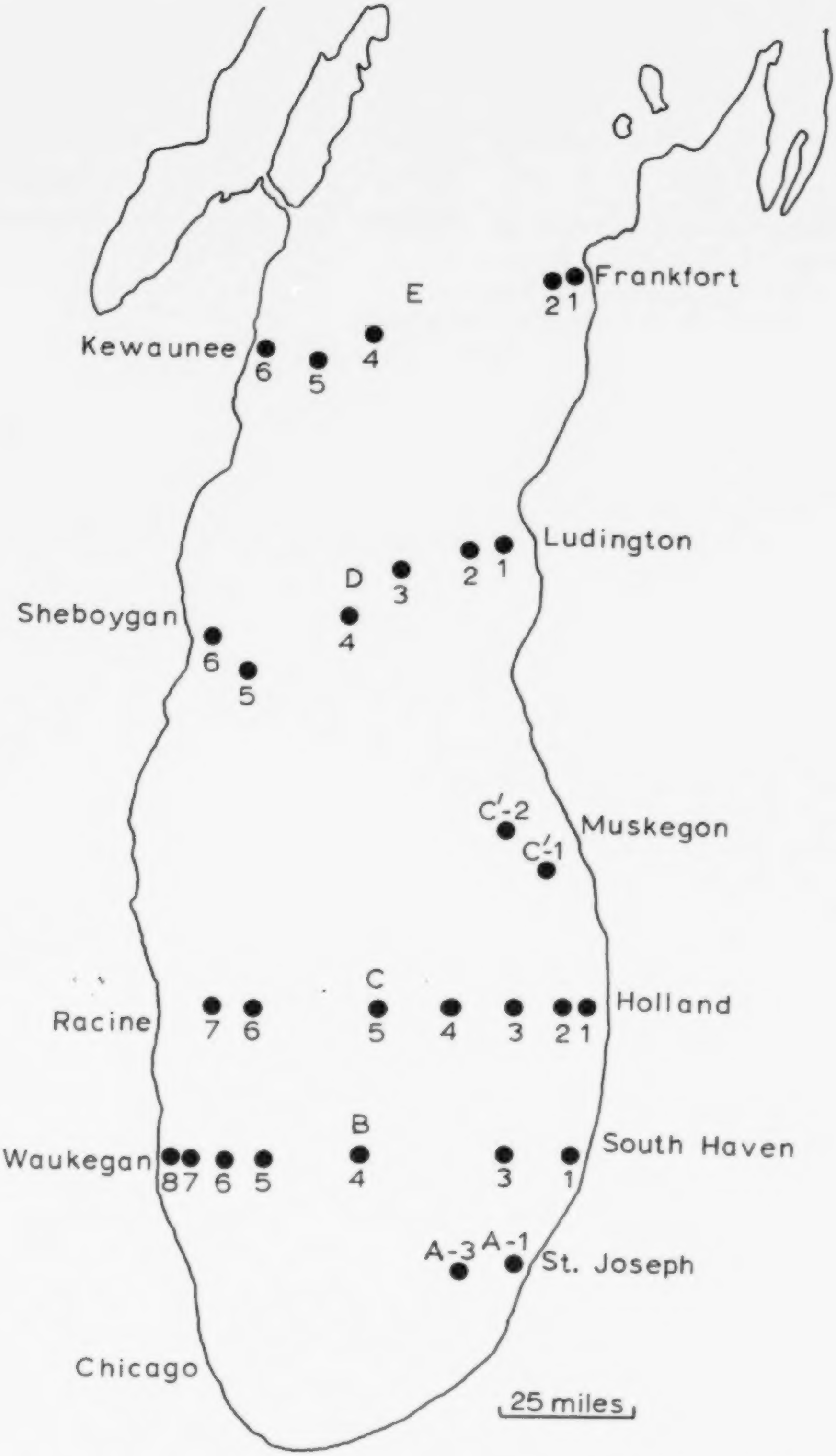
ROBERTSON, A. and W. P. ALLEY. 1966. A comparative study of Lake Michigan macrobenthos. Limnol. Oceanog., 11: 576-583.

__________, and C. F. POWERS. 1967. Comparison of the distribution of organic matter in the five Great Lakes. Great Lakes Res. Div., Univ. Mich. (In this report).

TABLE 1. The number of individuals per Smith-McIntyre sample of each sphaeriid species at each station in Lake Michigan.

1 = Sphaerium striatinum (Lamarck) form acuminatum
2 = Pisidium casertanum (Poli)
3 = P. compressum Prime
4 = P. nitidum Jenyns form pauperculum
5 = P. lilljeborgi Clessin
6 = P. conventus Clessin
7 = P. fallax Sterki
8 = P. henslowanum (Sheppard)
9 = S. nitidum Clessin
10 = P. idahoense Roper
11 = S. corneum (Linné)
12 = P. amnicum (Müller)

| Station | Depth | Species | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| B-8 | 11 | 10 | 44 | | 2 | 60 | | | 33 | | 5 | 38 | 12 |
| A-1 | 16 | | | | | | | | | | | | |
| C-1 | 17 | 3 | 16 | 3 | 2 | 1(?) | | | | | | | |
| B-1 | 20 | 7 | 15 | 10 | 8 | 29 | | 3 | 1 | 2 | | | |
| D-6 | 29 | | | | | 14 | 300 | | | 1 | | | |
| D-1 | 30 | | | | | 8 | 150 | | | 8 | | | |
| E-6 | 33 | | | | | | 100 | | | | | | |
| C'-1 | 38 | | | | | 10 | 125 | | | | | | |
| E-1 | 45 | | | | | 7 | 155 | | | | | | |
| B-7 | 46 | | | | | | 85 | | | | | | |
| C-2 | 47 | | | | | 3 | 93 | | | | | 1 | |
| C-7 | 55 | | | | | | 36 | | | | | | |
| B-3 | 65 | | | | | | 72 | | | | | | |
| A-3 | 71 | | | | | | 53 | | | | | | |
| C-3 | 79 | | | | | | 27 | | | | | | |
| B-6 | 88 | | | | | | 10 | | | | | | |
| C'-2 | 88 | | | | | | 35 | | | | | | |
| D-2 | 88 | | | | | | 24 | | | | | | |
| C-6 | 99 | | | | | | 6 | | | | | | |
| B-5 | 112 | | | | | | | | | | | | |
| C-4 | 113 | | | | | | 11 | | | | | | |
| D-5 | 119 | | | | | | 5 | | | | | | |
| B-4 | 130 | | | | | | 2 | | | | | | |
| D-4 | 143 | | | | | | | | | | | | |
| C-5 | 155 | | | | | | | | | | | | |
| D-3 | 175 | | | | | | 1(?) | | | | | | |
| E-5 | 177 | | | | | | 1(?) | | | | | | |
| E-2 | 200 | | | | | | 9 | | | | | | |
| E-4 | 219 | | | | | | | | | | | | |



Frankfort
E
2
1
Kewaunee
6
5
4
Ludington
D
3
2
1
Sheboygan
6
5
4
C'-2
Muskegon
C'-1
C
Racine
7
6
5
4
3
2
1
Holland
B
Waukegan
8
7
6
5
4
3
1
South Haven
A-3
A-1
St. Joseph
Chicago
25 miles

FIG. 1. Stations in Lake Michigan sampled for sphaeriids in August 1964.

# PRELIMINARY REPORT ON BIOLOGICAL OBSERVATIONS IN NORTHERN LAKE MICHIGAN UTILIZING SCUBA

Robert F. Anderson

Biological observations and studies utilizing SCUBA were undertaken during the summer field season of 1966 in conjunction with Dr. J. L. Hough's geological studies of northern Lake Michigan. Detailed biological observations of both the fauna and flora were made at some 26 stations ranging in depths from 10 to 120 ft.

Four genera of algae found to be most common were Chara, Nitella, Cladophora and Dichotomosiphon tuberosus. Chara and Nitella were common in bays and protected waters. Nitella was usually growing in deeper water than the Chara. However, large Chara beds were found at the base of a trench east of South Fox Island at a depth of 86 ft. Rocks in shoal areas were covered by a dense growth of Cladophora.

The benthic algae Dichotomosiphon tuberosus was observed to literally cover the bottom at several stations. The most abundant growth of Dichotomosiphon was located west of Garden Island Harbor in which the algae formed a mat 6 in. thick at a depth of 52 ft.

Freshwater hydra were commonly found attached to Chara and Cladophora. Bryozoans were observed attached to Chara and small rocks. Freshwater sponge was common in shallow waters being attached to either vegetation or rocks.

Crayfish were observed at nearly every station in various habitats ranging from rocky shoal areas to a clean sand bottom. During June the females observed were carrying either eggs or young. The crayfish, which is usually considered a bottom scavenger, was observed feeding on dead alewife and sculpins.

Mysids were abundant at all of the deeper stations and were most commonly found at the base of steep slopes. The mysids were observed swimming about an inch off the bottom.

Aside from the large schools of alewife observed, the next most common fish were the cottids. The sculpin, which is a bottom dweller, was observed at every station, being most abundant on a rocky bottom. Sculpins were also observed feeding on leeches and sticklebacks.

The brook stickleback Eucalia inconstans (Kirtland) and the ninespine stickleback Pungitus pungitus (Linnaeus) were found in shore-zone areas especially where vegetation was present on the bottom. In Sleeping Bear Bay the brook sticklebacks were found in areas where Chara and Dichotomosiphon tuberosus covered the bottom at depths of 40 to 60 ft. In July the ninespine sticklebacks were observed nesting in the bay. Nests were constructed of the algae Dichoto-

*mosiphon* and laid in small depressions on the bottom. Only the ninespine sticklebacks were observed nesting in the deeper waters of the bay at depths of 50 to 60 ft.

The American burbot, *Lota lota lacustris* (Walbaum) was observed during several dives. The burbot were found taking cover among boulders at depths of 62 ft and in among timbers of a shipwreck at a depth of 40 ft.

Aside from the direct biological observations, two other studies were undertaken in which SCUBA diving was used. One of the studies was designed to determine what effect, if any, fish have on the predation of benthic organisms. Aluminum enclosures were placed on the bottom and sampled by divers. Divers were used in another study to make actual field observations and photograph several grab type bottom samplers in order to determine their sampling characteristics and efficiency.

# DIRECT OBSERVATION FROM A SUBMARINE ON THE VERTICAL DISTRIBUTION OF MYSIS RELICTA IN LAKE MICHIGAN

Charles F. Powers, Andrew Robertson, and Robert F. Anderson

Recently the authors were afforded the unique opportunity of carrying out direct observations of the vertical distribution of the opossum shrimp, *Mysis relicta* Lovén, in Lake Michigan. Between 17 and 30 June, 1967 the two-man research submarine STAR II was leased from the Electric Boat Division of General Dynamics Corporation by The University of Michigan and carried out a number of exploratory dives in Lake Michigan. The primary purpose of these operations was to determine the usefulness of such vehicles in biological and geological exploration and research in the Great Lakes.

The present account concerns three dives made in the deepest part of the lake in a region about 25 miles southwest of Frankfort, Mich., U.S. Lake Survey navigation charts indicate a maximum depth in that region of 924 ft, the deepest sounding in the lake. The support vessel for the operation, the U.S.C.G. Cutter WOODBINE, located a maximum depth of 912 ft as indicated by its sonic sounding equipment, and it was at that point that the dives were carried out. Subsequent calculations based on readings obtained from the submarine's pressure gauge indicated depth to bottom to be about 860 ft, and this has been accepted here as the most probable depth. This is felt to be particularly justifiable since the echo sounder on the WOODBINE is calibrated in terms of the speed of sound in sea water.

A single dive was made by each of the authors at the same location. The duration of each dive was about one and three-quarter hours. The sequence of the dives was as follows:

Dive 1: Robertson. Time of dive 0748-0925 EST.
Dive 2: Powers. Time of dive 0950-1129 EST.
Dive 3: Anderson. Time of dive 1146-1330 EST.

Operational conditions were ideal. The day was calm, clear, and sunny, with practically no sea or swell. On the initial descent, Robertson noted numerous mysids below the 450 ft depth, and observed apparent discontinuities in their vertical distribution. During the ascent he attempted to obtain rough counts of their numbers with respect to depth by counting those seen through the forward viewport in the zone illuminated by the floodlights of the submarine. A similar procedure was followed by Powers and Anderson in the two subsequent dives. Powers was able to obtain counts on the way down, but temporary failure of the tape recording equipment negated results obtained during the ascent. Anderson succeeded in making counts both down and up.

The resulting counts, while sketchy and obviously subject to the errors inherent in attempting to enumerate small darting creatures through a small viewport from a moving submarine, are of considerable interest. They are summarized in Table 1. Two depth columns appear in the table, one designated "uncorrected" and the second "corrected." The uncorrected depth is that which was read directly from the depth dial on the pressure gauge in the submarine. The dial was calibrated for sea water, and hence yielded values which were less than actual depth in fresh water. The corrected depth is the depth of the submarine during the Lake Michigan dives as computed from the pressure in pounds per square inch measured by the pressure gauge.

TABLE 1. Results of Mysis relicta counts with respect to depth increments made from research submarine STAR II during three dives in Lake Michigan.

| Depth Ft. | | Dive 1 | Dive 2 | Dive 3 | |
|---|---|---|---|---|---|
| | | 0748 EST | 0950 EST | 1146 EST | |
| Uncorrected | Corrected | Ascent | Descent | Descent | Ascent |
| 400-450 | 410-461 | 2 | 0 | 0 | 0 |
| 450-500 | 461-512 | 8 | 2 | 0 | 2 |
| 500-550 | 512-563 | 45 | 11 | 1 | Very numerous |
| 550-600 | 563-614 | 51 | 45 | 9 | Very numerous |
| 600-650 | 614-666 | | 60 | 30 | 38 |
| 650-700 | 666-717 | 132* | 27 | 8 | 43 |
| 700-750 | 717-768 | | 32 | 3 | 28 |
| 750-800 | 768-819 | 11 | 19 | 8 | 11 |
| 800-840 | 819-860 | ** | ** | ** | |

*The 650 and 700-ft levels were not recorded, but observer verifies greatest abundance between 600 and 650 ft.

**Few specimens except near and on bottom where they were too numerous to enumerate.

During the counting procedure, the rate of descent and ascent of the vehicle was about 25 ft per minute—sufficiently slow to permit reasonably valid estimates of the numbers of mysids seen. Visibility was about 8 to 10 ft, and the floodlights were turned on throughout the counting procedure. The mysids were quite visible within the illuminated field in front of the submarine, appearing white and shiny in the reflected light. Most of those observed were oriented vertically in the water, and many gave the appearance of hanging motionless against the dark backdrop of the unlighted region beyond the field of view. Many others, however, were obviously in active swimming motion. The extent to which this activity was stimulated by the submarine is difficult to evaluate.

Although diving began at 0748 EST and terminated at 1330 EST, no difference in depth of light penetration was discernible to the three observers. In each case a very low level of ambient light could be distinguished at the 400-ft depth by looking toward the surface, but at 450 ft all apparent light had disappeared.

Striking similarities are apparent in the counts obtained on dive 1, dive 2, and the descent of dive 3. (Depths referred to here are the uncorrected depths as shown in Table 1, since it was to these depths that the observations were referred.) Only 2 mysids were seen above 450 ft during dive 1, and none during dives 2 and 3. Rapid increases in numbers of mysids occurred below 500 ft, with maximum numbers being found in all three cases at the 600 to 650-ft level. Although depth was inadvertently not recorded during dive 1 at 650 and 700 ft, the observer confirms that he saw the largest numbers between 600 to 650 ft. A gradual tapering off in the counts is noticeable below 650 ft. This continued until near the bottom, where the numbers of mysids increased again. Most of these organisms were on the bottom itself, but some were seen swimming up to a height of 10 to 15 ft. In this bottom and near-bottom zone it was not possible to obtain numerical estimates, but the animals appeared to be at least as numerous as in the water column above. Mysids were literally "everywhere."

The counts obtained during the ascent of dive 3 are somewhat at variance with the other findings. It is possible that the observer had simply become more accustomed to conditions by the time the submarine began its ascent, since he recorded much greater quantities of mysids at practically all depths than during the descent. However, the most obvious difference between these counts and the other three sets is the observation "very numerous" between 500 and 600 ft (cf. Table 1). The observer reported that mysids occurred there in quantities too great to permit attempts at enumeration. They appeared to him to be particularly dense at about 520 ft. These observations would place the maximum concentration of mysids at a somewhat shallower depth than indicated by the other data.

It is obviously not possible to draw any precise conclusions regarding the vertical distribution of Mysis from the data presented here. This single exploratory mission, however, has shown that direct observation of these organisms is feasible, and that useful and unique data can be obtained by such means. It is evident that, on the day of observation, two distinct concentration zones of mysids existed, one about 200 to 250 ft off bottom, and the other at the bottom. Three out of four sets of observations placed the shallower concentration at a depth of 600 to 650 ft (614 to 666 ft corrected). Further, with the possible exception of the first two mysids sighted on dive 1, all were positioned below the depth at which ambient light was discernible to the eye.

Further useful information was derived from these dives with respect to the abundance of amphipods at these great depths. Grab samples taken by us over the past several years have indicated that amphipods are relatively scarce in such regions, reaching their peak abundance where depth to bottom is about 150 ft and decreasing rapidly at greater depths (Powers and Robertson, 1965; Robertson and Alley 1966; Powers and Alley 1967). This was confirmed during the time the submarine was operating on bottom, when a total of only about 20 amphipods were sighted swimming just above bottom by the three observers. Although amphipods are certainly the dominant benthic organism in more moderate depths, they are replaced by mysids in the deepest parts of the lake. Reliable quantitative sampling of the mysid population must be developed in order to evaluate their relationship with the amphipods, particularly in terms of the relative abundance of these two groups of organisms in various depth zones in the lake.

## REFERENCES

POWERS, CHARLES F., and WAYNE P. ALLEY. Some preliminary observations of the depth distribution of the macrobenthos of Lake Michigan. (In this final report.)

__________, and ANDREW ROBERTSON. 1965. Some quantitative aspects of the macrobenthos of Lake Michigan. Proc. 8th Conf. on Great Lakes Res.: Univ. of Mich., Great Lakes Res. Div. Pub. 13: 153-159.

ROBERTSON, ANDREW, and WAYNE P. ALLEY. 1966. A comparative study of Lake Michigan macrobenthos. Limnol. and Oceanog. 11(4): 576-583.

# WATER QUALITY AND EUTROPHICATION TRENDS IN SOUTHERN LAKE MICHIGAN*

Charles F. Powers and John C. Ayers

## INTRODUCTION

The work reported upon here constitutes a part of a study of Lake Michigan which has been aimed primarily at the assessment and evaluation of long-term environmental changes. Another part of this work has already been reported (Ayers 1965). The present report deals with the use of historical records of data collected near shore, over periods of at least 20 continuous years, in the study of temporal change in water quality and hence the environment of Lake Michigan. Other workers, principally Beeton (1965,1966), and Ownbey and Willeke (1965) have utilized historical data in similar studies. It is apparent from their work and from that reported here that long-term changes in the chemistry of Lake Michigan are and have been occurring, and that they will undoubtedly continue to occur for some time into the future. The ecological impact of such change is yet to be thoroughly assessed, and in some instances it is not presently possible to ascertain what the ultimate effects will be. Studies which attempt reconstruction of the past history of this and other large, economically important, lakes provide not only a base line on which future work may be predicated but also furnish reliable estimates of past conditions and the rates at which those conditions are undergoing alteration.

Many persons have assisted strongly in the compilation of the data utilized in this report. Obviously, all cannot be named here, but the authors wish gratefully to acknowledge the kind assistance and generous hospitality extended at the filtration plants which were visited for data collection purposes. We would particularly like to thank Mr. James W. Jardine, Commissioner, and Mr. H. H. Gerstein, Department of Water and Sewers, Chicago; Mr. F. A. Underwood, Superintendent of Filtration, Milwaukee; and Mr. Donald E. Hazelswart, Water Plant Supervisor, Grand Rapids.

## SELECTION OF NEAR-SHORE DATA SOURCES

One of the major premises of the research plan was that nearshore water quality data, particularly as collected by filtration plants, can be utilized as indicators of the condition of adjacent open-lake waters. It was immediately evident from the compilation of nearshore data sources for the Great Lakes assembled by Powers, Jones, and Ayers (1959) that filtration plants represented the best possible sources of data for southern Lake Michigan.

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Although a number of municipalities utilize the southern basin of the lake as a source of domestic water supply, the plants serving Grand Rapids, Mich., Chicago, Ill., and Milwaukee, Wis., were ascertained to represent the greatest potential usefulness in a study of the kind contemplated. Michigan City, Ind., and Whiting, Ind., were, in addition to the above three localities, believed to be of limited potential usability. The criteria for selection of data sites were: kinds and frequency of analyses and observations made relating to quality of lake water, location of raw water intake with respect to distance from shore, geographical location of the plant with respect to potential representativeness of a specific region of the lake, and the period of record over which results of analyses and observations were available. These criteria are discussed below.

## KINDS AND FREQUENCY OF ANALYSES AND OBSERVATIONS

Most of the plants drawing water from Lake Michigan do not conduct a sufficient number of kinds of analyses on the raw lake water to contribute significantly to a study of this kind. The most numerous analyses are made at Chicago and this location, along with Grand Rapids and Milwaukee, far exceeds all other plants on southern Lake Michigan in number of kinds of analyses performed. Those analyses examined in the present study are given in Table 1.

In addition to Chicago, Grand Rapids, and Milwaukee, the next most nearly complete series of analyses are performed on samples taken from Michigan City and Whiting, Ind., intakes and published by the Indiana State Board of Health and Stream Pollution Control Board. The usefulness of these data, however, is limited by two factors: (1) The period of record extends back only to 1957, and (2) the Whiting intake is only 1696 ft from shore, and the Michigan City intake 3000 ft. The importance of intake location is discussed below. However, Risley and Fuller (1965) have shown that various chemical parameters indicate increased rates of concentration of ions in the extreme south end of the lake. In view of this condition the Whiting and Michigan City plants were included for consideration in this study.

## INTAKE LOCATION

Powers et al. (1960), in studies of Lake Erie designed to assess the usability of filtration plant data, showed that intakes located less than 4000 ft from shore yielded data of uncertain reliability, while the reliability of intakes farther from shore was much greater. The intakes at Grand Rapids and Milwaukee are greater than one mile from shore, and those at Chicago at least two miles off (Table 1).

Six different intakes have served Chicago at various times during the period over which data are available. They are listed in north to south order in Table 1. The Chicago water supply system is divided into the North, Central, and South Water Districts. The 4-Mile, Dever, Harrison, and 2-Mile cribs, of which only the Dever is presently in operation, have all at various times served the

TABLE 1. Summary of characteristics of Grand Rapids, Chicago, Milwaukee, Michigan City, and Whiting filtration plants.

| Plant | Period of record | Intake Location | | | Plant analyses used in this study |
|---|---|---|---|---|---|
| | | Dist. from shore | Depth | Depth of lake | |
| Grand Rapids | 1941 - present | 6,100' (7-1/2 mi south of Grand Haven) | 57' | --- | calcium, magnesium, total solids, chloride, sulfate, silicon dioxide |
| Chicago<br>6 intakes: | 1926 - present* | | | | calcium, magnesium, total solids, chloride, sulfate, silicon dioxide |
| Dunne crib | | 10,525' | 18' | 32' | |
| 4-Mile crib** | | 16,600' | 29' | 38' | |
| Dever crib*** | | 13,800' | 25' | 34' | |
| Harrison crib*** | | | | | |
| 2-Mile crib*** | | | | | |
| Wilson crib | | 11,000' | 22' | 33' | nitrate-N<br>total phosphate, orthophosphate |
| Milwaukee | 1930 - present | 6,554' (NE of North Point) | 55' | 67' | calcium, magnesium, total solids, chloride, sulfate, silicon dioxide, nitrate-N |
| Michigan City | 1957 - present | 3,000' | 35' | --- | total solids, chloride nitrate-N, total-P |
| Whiting | 1957 - present | 1,696' | 16' | --- | total solids, chloride, nitrate-N, total-P |

*The periods of record for orthophosphate and total phosphorus at Chicago are from 1949 and 1961, respectively.

**4-Mile crib discontinued in 1957.

***Harrison and 2-Mile cribs replaced by Dever crib in 1936. The Harrison crib was located just north of the present Dever crib, and the 2-Mile crib was slightly inshore of the Harrison.

Central District. Despite these changes in intakes, Central District water has always come from the same general locality and samples from this District over the period of record should be internally comparable.*

The North District has always drawn on the Wilson crib, and the South District, the Dever crib. Since construction of the South District Filtration Plant in 1945, a shore intake located at the plant has been used to supplement the raw water supply intermittently during the summer, so that the water upon which the chemical analyses are based at such times is actually a mixture of water from the Dunne crib and the shore intake. It should also be noted that from 15 August 1945 until 4 April 1947 the shore intake was the sole source of water for the South District.

As pointed out earlier, the intakes at Michigan City and Whiting are considerably closer to shore than those at Grand Rapids, Chicago, and Milwaukee, but in view of their strategic location and the known increased pollution of that area of the lake, data from those plants have been considered in the present study. Their locations are included in Table 1.

## GEOGRAPHICAL LOCATION

On the basis of location the Grand Rapids intake represents the east side of the lake where the effects of runoff should be most pronounced, since about 80% of the drainage from the watershed of the southern basin of the lakes enters the east side. The Chicago intakes, being near the south end of the lake, could be expected to sample the integrated product of the southern basin. The Milwaukee intake is situated at the extreme northwest portion of the southern basin, and should provide comparative data on the quality of water in that region. The Michigan City and Whiting intakes sample the extreme south end where the most serious effects of pollution are indicated.

## PERIOD OF RECORD

The lengths of time for which records of chemical analyses are available at Grand Rapids, Chicago, and Milwaukee are sufficient to permit reasonably long-term reconstruction of past trends of measured parameters. The greatest period of record is at Chicago, where records of analyses conducted since 1926 are available. Records at Milwaukee are available to 1930, and at Grand Rapids from 1941.

Records for Michigan City and Whiting exist only from 1957, and are therefore not of sufficient length to permit reconstruction of past trends in water quality change. There are, however, sites at which the quality of the lake water in the extreme south end is frequently monitored and must therefore be considered the best existing indicators of present trends in that part of the lake.

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*All data for this report were compiled before operation of the new Central District Filtration Plant was begun.

## TREATMENT OF DATA

### GENERAL CONSIDERATIONS

Probably the greatest obstacle to the use of water chemistry data from the filtration plants is one with which one is confronted whenever using data collected by others: confidence in its reliability and representativeness. This problem is enhanced with regard to the plants in that many data are used which were collected at remote times, in many cases by personnel since departed. However, the data at the selected plants represent, insofar as it has been possible to determine, the best body of data collected at single sampling stations over a significant time period, and are the best key we have to the past history of the lake environment.

In the use of such data, particularly with regard to the historical reconstruction of the occurrence of various chemical parameters, some of the more critical of the variety of unknowns which may be encountered are: the abilities and reliability of technicians performing the analyses; the methodology employed; laboratory and personnel changes; changes in intake locations; the degree to which a given sample is representative of prevailing conditions in the lake; and the actual number of samples upon which a "yearly average" (a frequent method of reporting) is based. If sampling has not been performed on at least a seasonal basis, the factor of possible seasonal variation in certain parameters may bias the calculation of "yearly average" values. With regard to the plants utilized in this study, it has been possible to answer some of these questions. In all cases, for the entire period of record, the intake locations, the frequency of sampling (and, hence, seasonal variations), and any changes in laboratories performing the analyses are known. Information on past methodology and personnel is more difficult to obtain; there is usually no record. This being the case, pertinent literature has been searched, with careful attention given to past editions of "Standard Methods" to ascertain as fully as possible the most likely methods of analysis being used in water chemistry laboratories during any particular time in the past. Particular attention has been paid to this point as well as to the possibility of laboratory changes when suspicious changes in the temporal trend of particular parameters at a given plant have been noted.

### GUIDING PHILOSOPHY OF TREATMENT OF FILTRATION PLANT DATA

It is felt that continuing analyses performed on raw lake water at the filtration plants over a substantial period of years constitute a ready means of evaluating past changes in the quality of the lake water, particularly if trends in the occurrence of particular chemicals can be further correlated with available older analyses of lake water performed by various individuals in the latter 19th and early 20th centuries. Most of the chemical constituents determined at the plants are those whose occurrence is related to the influence of human population. These would include such substances as nitrogen, phosphorus, chloride, and sulfate. On the other hand, plant analyses for calcium and magnesium, which are little affected by population and would most logically be expected to represent the natural rate of contribution of allochthonous materials to the lake from its drainage basin, are also available. If these can be taken as controls, the rate of change of substances bearing a relationship to human population may yield significant information on accelerated eutrophication rates, if such are found to exist.

## THE DATA

### Chicago

Since the Chicago water supply has always utilized multiple intakes, the same analyses are performed separately upon samples from each one. Until 1961, "spot" samples were taken, that is, sampling was done on a single date several times during the year. Since mid 1961, some sampling has been on a "composite" basis, that is, samples are collected daily for a period of one to several weeks, **mixed** in a common container, and all determinations except those which would be subject to deterioration with time performed on the composite. Samples for analyses which would be affected by storage (such as nitrogen and phosphorus) are collected on the last day of the composite period. Frequency of sampling at Chicago and corresponding years was as follows:

| Times per year | Years |
|---|---|
| 1 | 1930, 1932, 1933, 1934, 1935, 1938, 1941, 1943, 1946, 1948, 1949 |
| 2 | 1929, 1931, 1936, 1937, 1939, 1940, 1942, 1944, 1945, 1947, 1952, 1955, 1958, 1960 |
| 3 | 1928, 1954, 1956, 1959, 1961, 1962 |
| 4 | 1950, 1951, 1953, 1957 |
| - | |
| 6 | 1927 |
| - | |
| 12 | 1926 |

Eleven of 37, or slightly less than one-third, of the years contained within the period of record were sampled only one time. Such infrequency does not stimulate confidence in the reported values being representative of the yearly average; however, they appear reliable and logical when incorporated into regressions of the various parameters aginst time.

One important laboratory change has occurred at Chicago. Prior to 1948, analyses were conducted by the Chicago Department of Health. Since that time, all analytical work has been carried out at the South District Filtration Plant.

The analyses performed at Chicago which have proven useful in the present investigations are listed in Table 1. Numerous other determinations, particularly for various metals, are also made, but are less suitable for the examination of historical trends in lake water quality, or else contribute no information which would supplement that gained from the parameters utilized here.

## Milwaukee

Data were obtained from the Milwaukee plant as yearly averages. The period of record is from 1930 to the present. Beginning with 1939, two values were reported for most parameters. One set is designated "mineral analysis" and the other "sanitary analysis." The mineral analyses, represented by total solids, total hardness, total alkalinity, calcium, magnesium, iron, sulfate, silicon dioxide, sodium plus potassium, nitrate-nitrogen, and turbidity, are performed on samples collected seasonally and are based on gravimetric procedures. The sanitary analyses, which include total solids, total hardness, total alkalinity, iron, chloride, nitrate-nitrogen, and turbidity, are performed on samples collected at least monthly and are based on titrimetric and colorimetric procedures. The sanitary analyses have been used wherever possible in this study because of the more frequent sampling upon which they are based. So far as is known, composite sampling is not employed. No data appear for the years 1931, 1937, and 1938.

Information gained from the plant has indicated that only the North Point intake has been in use during the period of record included in the present study. However, results prior to 1939 are generally quite variable and do not appear as reliable as those reported subsequently. A new intake, located 7600 ft from the south shore of Milwaukee Bay, was put into service in June 1962. None of the data considered in this report are based on water from that intake.

The Milwaukee plant is now a part of the National Water Quality Network and data are presently being reported, at least in part, in the Annual Report of the Network.

Grand Rapids

Data obtained from the Grand Rapids plant were **not** averages, but were in the form of single sets of analyses conducted on samples taken on specific dates. Yearly frequency of sampling has varied as follows:

| Times per Year | Years |
|---|---|
| 0 | 1958 |
| 1 | 1942, 1959 |
| 2 | 1943, 1954 |
| 3 | 1946, 1951, 1953 |
| 4 | 1949, 1957 |
| 5 | 1945, 1947, 1950, 1952, 1960, 1961 |
| 6 | 1955 |
| 7 | 1941, 1948 |
| 8 | 1944 |
| 9 | 1956 |

Sampling at Grand Rapids has, on the whole, been of sufficient frequency to permit the computation of yearly averages with little seasonal bias. The analyses used in the present study appear in Table 1.

Except for five composite samples taken in 1948, all sampling appears to have been on a "spot" basis. The same intake has been in use since the city of Grand Rapids began taking its water from Lake Michigan. Analyses are, for the most part, based on gravimetric methods.

## LEVELS AND TEMPORAL TRENDS OF CHEMICAL PARAMETERS MEASURED AT FILTRATION PLANTS

Unless otherwise stated, all values used in the following presentation are in the form of yearly averages. Averages for Chicago for any given year have been computed using data from all operating intakes. The data have been treated from the standpoint of variation from year to year, with a view toward the detection of any long-term trends in the concentrations of the various chemicals in the lake water. Plots of various chemical parameters against time, in the form of yearly averages versus year, have been made using data from the several plants, and in most cases regression lines have been calculated. The time periods considered are: Chicago, 1926-62, except where noted; Milwaukee, 1939-62; Grand Rapids, 1941-61; Michigan City and Whiting, 1957-64.

The rate of temporal change of some parameters at Chicago appeared to increase with the shift in laboratories in 1948, indicating greater rates of accumulation of certain chemicals in the lake water since 1948 than for the period

1926-47. For this reason, regressions have been computed for the various parameters for the period 1948-62 as well as for the entire period of record. This has also been done, for purposes of comparison, for the Milwaukee and Grand Rapids data. Increases in rates of accumulation, by this method, appear to have occurred for the 1948-62 period at Milwaukee and 1948-61 period at Grand Rapids as well as at Chicago, suggesting that the rate change first noted at Chicago is a real change.

## CALCIUM AND MAGNESIUM

As stated earlier, it might reasonably be assumed that calcium and magnesium, whose rates of accumulation in natural bodies of water are little affected by the discharge of waste materials from human populations, might serve as convenient indicators of the natural rates of accumulation of allochthonous materials in the waters of Lake Michigan. Accordingly, calcium and magnesium data from Chicago, Milwaukee, and Grand Rapids were plotted against time and regressions calculated (Figs. 1 and 2).

Indicated trends of the regression lines for calcium are very slight and are obviously not significant; data from all three plants strongly suggest that no change in calcium concentration has occurred in the lake. This is in agreement with Beeton (1965) who concluded that no increase in calcium has occurred in Lake Michigan. The regressions do indicate differences in the calcium content of the lake water in the regions represented by the three different plants. The median values over the periods of record, as read from the regressions, are as follows: Grand Rapids 35.8 ppm, Milwaukee 35.5 ppm, Chicago 32.8 ppm. The possibility that these differences may be real is suggested from the results of Ayers et al. (1958), who conducted four synoptic surveys of the lake in the summer of 1955. On three of the four occasions, they found calcium levels to be somewhat higher on the eastern (Grand Rapids) side of the southern basin than in the Milwaukee and Chicago regions.

Regressions of magnesium show similarly slight trends but, unlike calcium, do not suggest differences among the regions represented by the three plants. Median values were, for Grand Rapids 10.8 ppm, for Milwaukee 11.0 ppm, and for Chicago 10.7 ppm, all very nearly the same value.

It appears from the data of the three above plants that, over the periods of record represented, no significant changes in the calcium or magnesium content of the lake water have occurred.

## SULFATE

Regressions of sulfate on time appear in Fig. 3. From the aspect of the entire period of record for each plant, increases in sulfate concentration appear to have occurred at Grand Rapids and Chicago but not at Milwaukee. The essentially horizontal regression line in the latter case, however, results from a series of

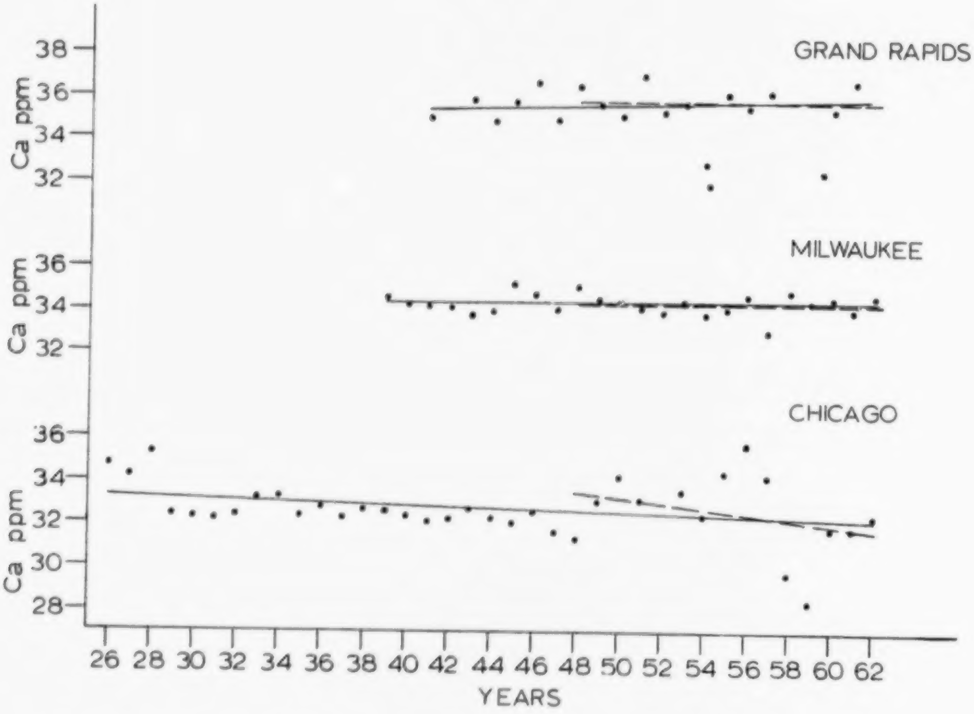


FIG. 1. Calcium vs. time at Grand Rapids, Milwaukee, and Chicago.

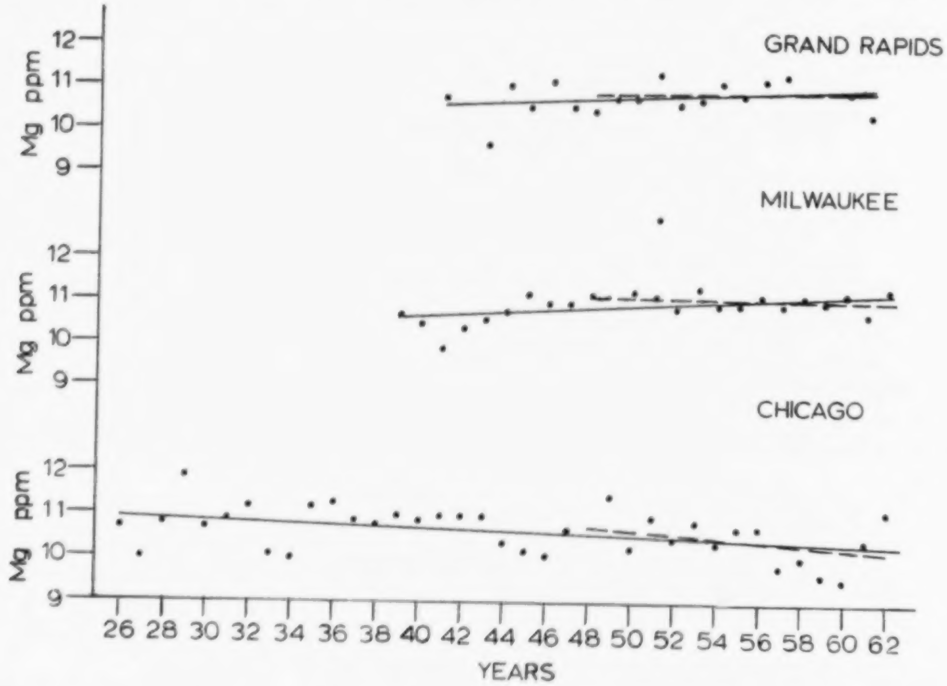


FIG. 2. Magnesium vs. time at Grand Rapids, Milwaukee, and Chicago.

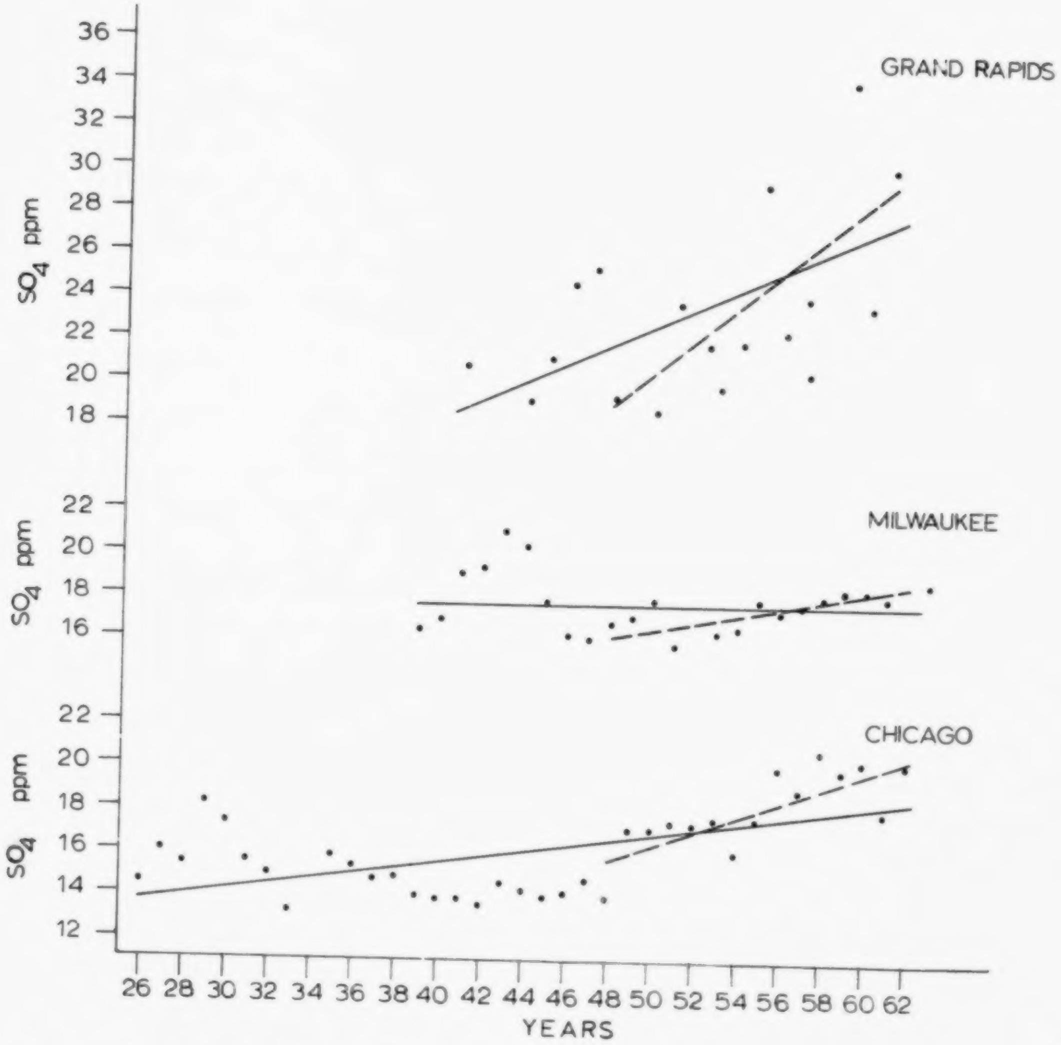


FIG. 3. Sulfate vs. time at Grand Rapids, Milwaukee, and Chicago.

high yearly averages reported for the years 1941 through 1944. There is no ready explanation for these high values. Since 1948, sulfate at Milwaukee shows a definite increase.

Comparison of the slopes of the regressions at all three plants for the 1948-62 period with corresponding slopes for the entire period of record shows an accelerated rate of sulfate increase for the latter period. Over the period of records of the several plants, indicated increases in sulfate based on the regression lines are as follows:

Milwaukee: no change
Chicago: 13.8 to 18.6 ppm (+ 4.8 ppm)
Grand Rapids: 18.9 to 27.6 ppm (+ 8.7 ppm).

Comparison of the 1948-62 regressions for the three plants shows increases for that period as follows:

Milwaukee: 16.2 to 18.8 ppm (+ 2.6 ppm)
Chicago: 15.8 to 20.6 ppm (+ 4.8 ppm)
Grand Rapids: 19.1 to 29.4 ppm (+ 10.3 ppm)

Median values for the 1948-62 interval were: Milwaukee 17.6 ppm, Chicago 18.2 ppm, Grand Rapids 24.2 ppm.

Sulfate was not measured at Michigan City and Whiting.

## CHLORIDE

Regressions for chloride (Figs. 4 and 5(a)) show definite increases at all three locations. Chloride at Milwaukee did not imitate the high sulfate values in the early 1940's. The rate of chloride increase shows an acceleration for the period 1948-62, as did sulfate, at Grand Rapids, Chicago, and Milwaukee. There is little difference in median chloride levels as measured at the three plants, although Milwaukee is consistently below Chicago and Grand Rapids.

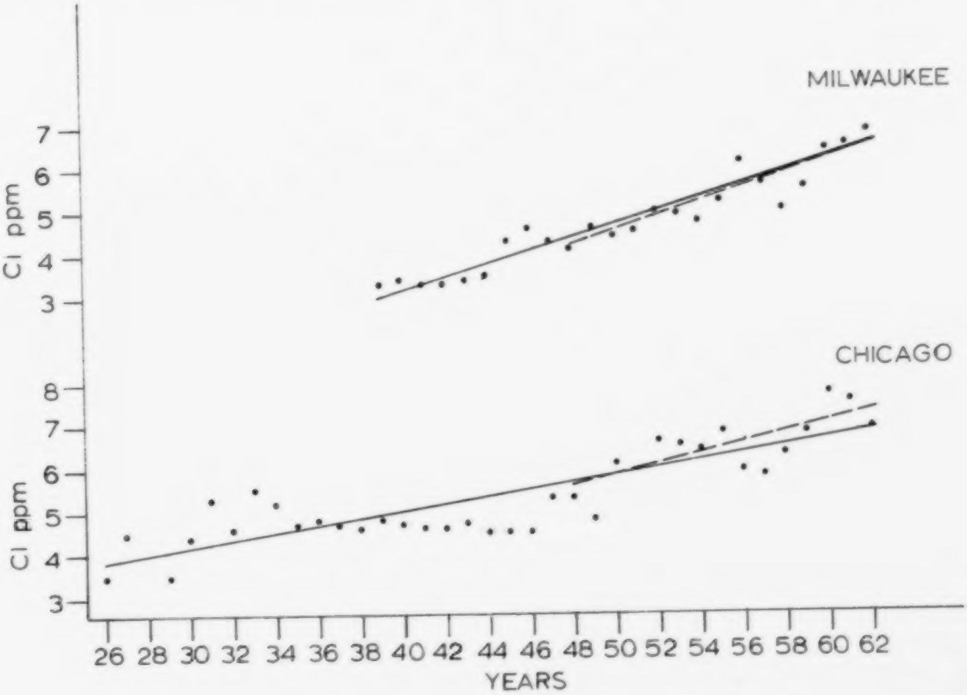


FIG. 4. Chloride vs. time at Milwaukee and Chicago.

Chloride is also measured at Michigan City and Whiting. Although the regressions for parameters at Chicago and Milwaukee have been computed through 1962, and at Grand Rapids through 1961, data from Chicago and Milwaukee for the years 1963 and 1964 were more recently obtained. Utilizing these data, chloride levels at Michigan City and Whiting have been compared with those at Chicago and Milwaukee for the period 1957-1964 (Fig. 5(b)). Although values from Whiting are usually highest, chloride levels in general do not vary greatly among the four locations. Michigan City and Whiting had the same yearly average values in 1957 and 1964, but during the intervening years Michigan City was consistently lower by 1 to 2 ppm. Interestingly enough, the highest average chloride value exhibited during this period was at Chicago, where in 1964 it was 9.7 ppm.

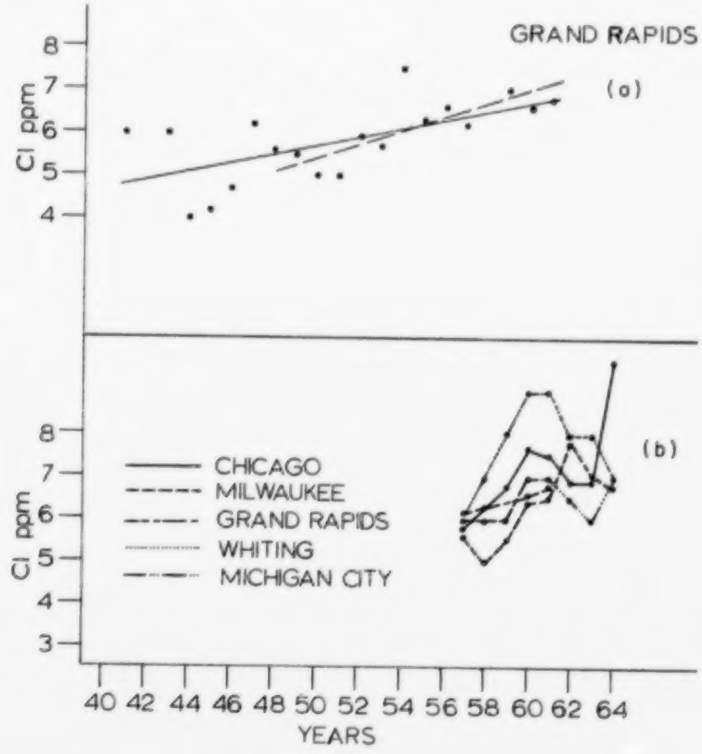


FIG. 5. (a) Chloride vs. time at Grand Rapids (b) Comparison of chloride at Chicago, Milwaukee, and Grand Rapids with chloride at Whiting and Michigan City.

## TOTAL SOLIDS (RESIDUE ON EVAPORATION)

Regressions of total solids (residue on evaporation) on time appear in Figs. 6 and 7(a). Regressions were not computed for the 1948-62 period as has been done with other parameters; the extreme year to year variability exhibited by this quantity precluded the usefulness of the additional calculations in this case.

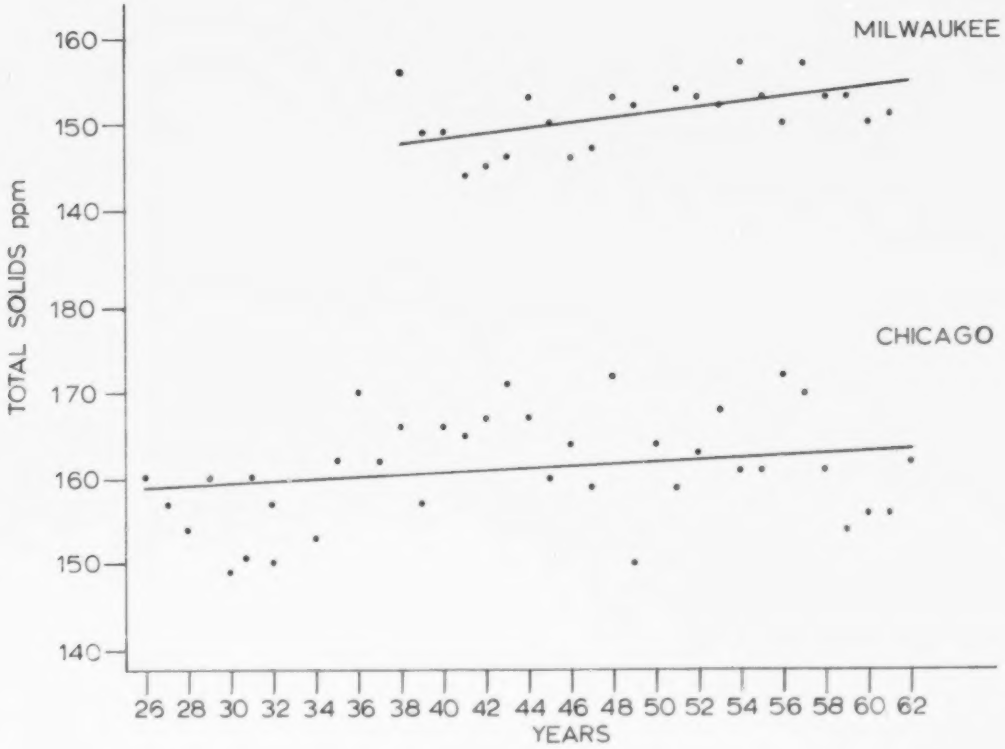


FIG. 6. Total solids vs. time at Milwaukee and Chicago.

Over the period of record of Grand Rapids, Chicago, and Milwaukee, a net increase in total solids is indicated by the slopes of the regressions. At Grand Rapids the increase is about 14 ppm during the period 1941-61; at Chicago, about 5 ppm during the period 1926-62; and at Milwaukee, about 7 ppm from 1939 to 1962. Additional total solids data, collected between the years 1895 and 1908, are also available for the Chicago area. These data, from analyses performed on intake water from Chicago, Waukegan, and Lake Forest permit calculation of the Chicago regression over a 67-year period. From this, an increase in total solids of about 14 ppm (151 to 165 ppm) is indicated for the region from 1895 to 1962. This regression compares quite favorably with that computed for the 1926-1962 period, and is practically a backward extension of the trend indicated for the shorter period. This is in fairly good agreement with Beeton (1965) who showed a change in total dissolved solids since 1895 of 20 ppm. His absolute values, however, are lower than those of the present report, with his values increasing from about 130 to about 150 ppm.

Total solids are measured at Michigan City and Whiting. Yearly averages for those plants have been plotted in Fig. 7(b) for the period 1957-1964, along with plots of the data for the same interval from Chicago, Milwaukee, and Grand Rapids (data available only to 1961 from the latter location). Levels of total solids at both Michigan City and Whiting are generally higher than at the other

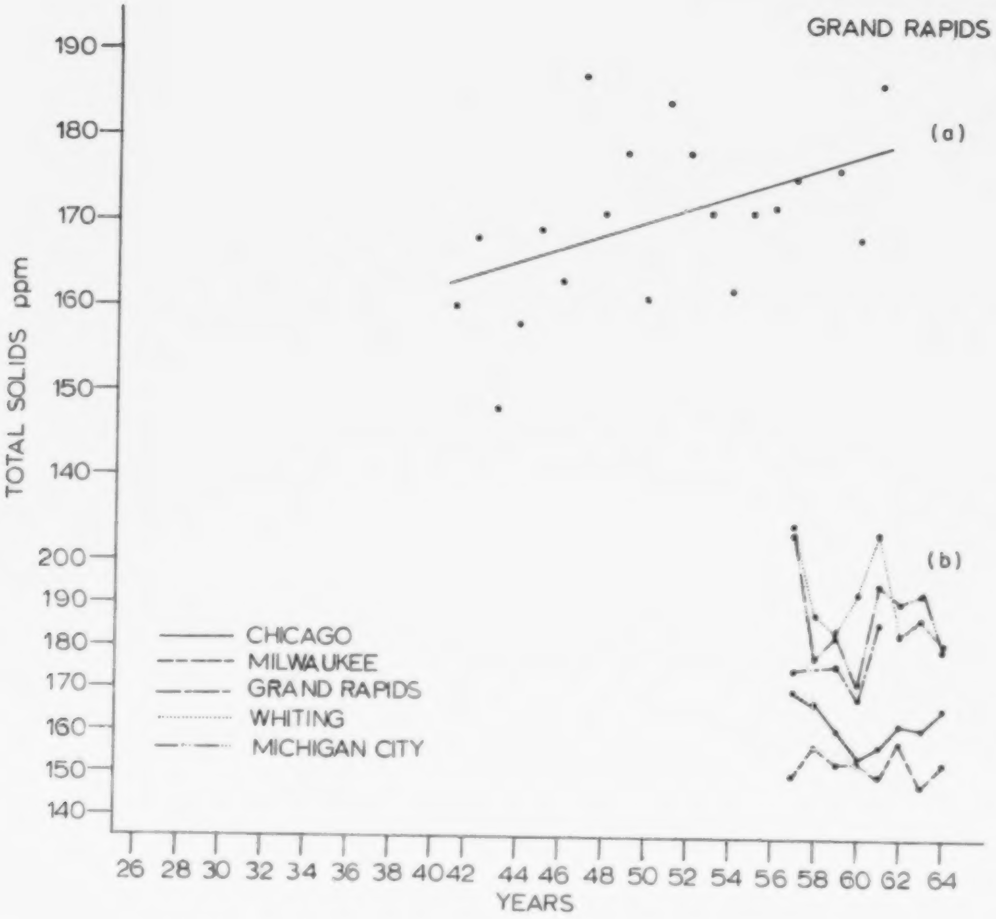


FIG. 7. (a) Total solids vs. time at Grand Rapids.
(b) Comparison of total solids at Chicago, Milwaukee,
and Grand Rapids with total solids at Whiting and
Michigan City.

three plants, although there is some overlap with Grand Rapids. Michigan City is somewhat lower than Whiting, as was also observed with respect to chloride.

SILICA

Regressions of silica on time are presented in Fig. 8. Note that the period of record for silica at Grand Rapids extends back only to 1944. Regressions over the entire period of record exhibit a negative slope at each plant, indicating decreasing silica concentration with time. Only at Chicago, however, does the downward trend appear to have been consistent over the entire period of record. In fact, at Milwaukee an increase is indicated until about 1948, from which time the year-to-year plots show a definite downward trend. The trends for the period 1948-62 are decidedly negative at all three plants.

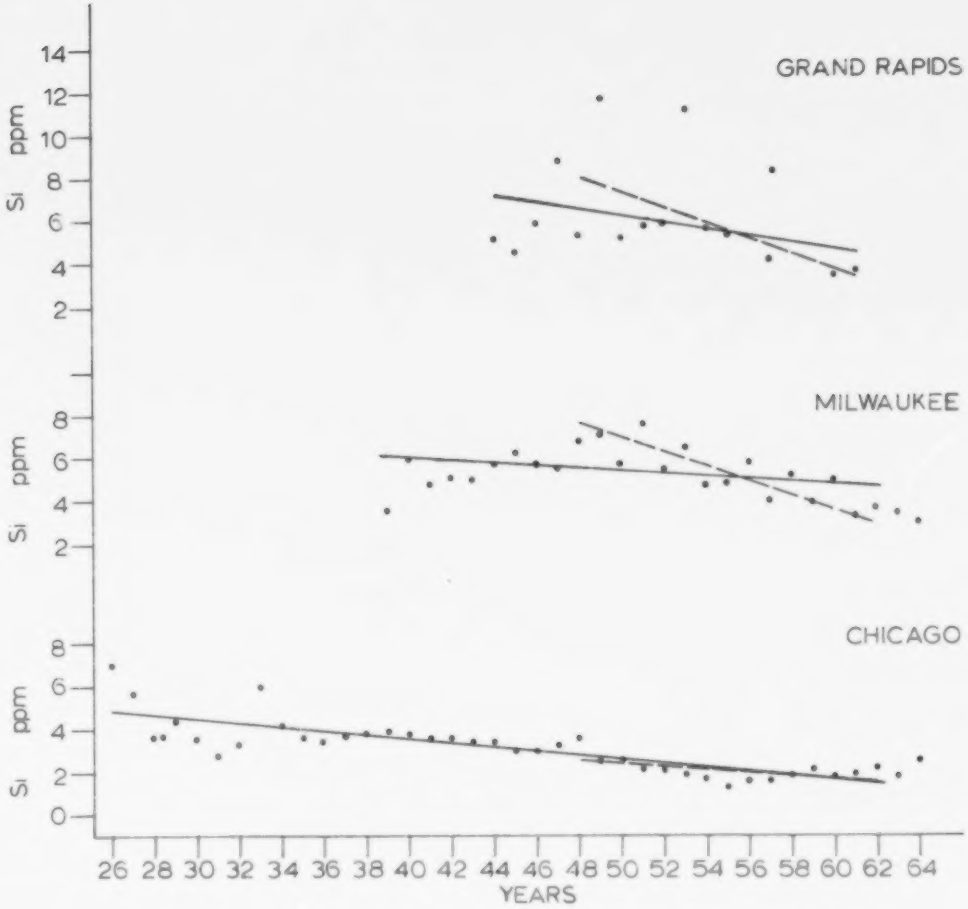


FIG. 8. Silica vs. time at Grand Rapids, Milwaukee, and Chicago.

From the 1948-62 regressions, silica appears to have decreased since 1948 about 4.5 ppm at Grand Rapids, about 5 ppm at Milwaukee, and only about 1 ppm at Chicago. The indicated rate of decrease is about the same for Grand Rapids and Milwaukee, and much less for Chicago. However, it is difficult to decide just how the data for the former two locations should be interpreted; some very widely scattered points exist in the Grand Rapids data, and the upward trend from 1938 to 1948 at Milwaukee introduces considerable uncertainty there. Silica is the only parameter examined at any of the plants which tends to show a net decrease with time. It is not a conservative parameter, being affected biologically through its incorporation into diatom tests. Damann (1960), from examinations of plankton data collected at Chicago, has demonstrated a significant increase in the standing crop of plankton over the period 1926-58. The occurrence of silica would be expected to vary inversely with plankton (diatoms are the predominant phytoplankters in Lake Michigan) and its continuing decrease in the lake water might therefore be a reflection of increased biological productivity. That silica may actually undergo such a decrease with increasing eutrophication is further suggested by the fact that Lake Erie, generally acknowledged to be the most eutrophic of the Great Lakes, and Lake Ontario, situated down-gradient from

Lake Erie, have the lowest overall silica contents of any of the Great Lakes. According to Beeton and Chandler (1963), the average silica content of the Great Lakes is as follows: Superior 2.1, Huron 2.3, Michigan 3.1, Erie 1.5, and Ontario 0.3 ppm.

## NITROGEN AND PHOSPHORUS

Nitrogen in the nitrate, nitrite, albuminoid, and ammonia forms has been measured at Chicago since 1926. Nitrate-nitrogen has been measured at Milwaukee over the entire period of record of that plant, and at Michigan City and Whiting since 1957. No nitrogen analyses exist for Grand Rapids.

Regressions were calculated for nitrate-nitrogen at Chicago and Milwaukee for the entire periods of record only and appear in Fig. 9. Note that the slope is positive at Chicago and negative at Milwaukee. The positive slope which describes the Chicago data results from an increase between 1948 and 1955; values since 1955 have steadily decreased. The overall decrease at Milwaukee as opposed to the increase at Chicago is not readily explained. The considerable variability of nitrate is particularly evident from the scatter of the points about the regression lines, and it is quite likely that regressions on this parameter are not particularly meaningful. It is also evident that the levels of nitrate at Chicago and Milwaukee are about the same, even though the trends of the regressions differ.

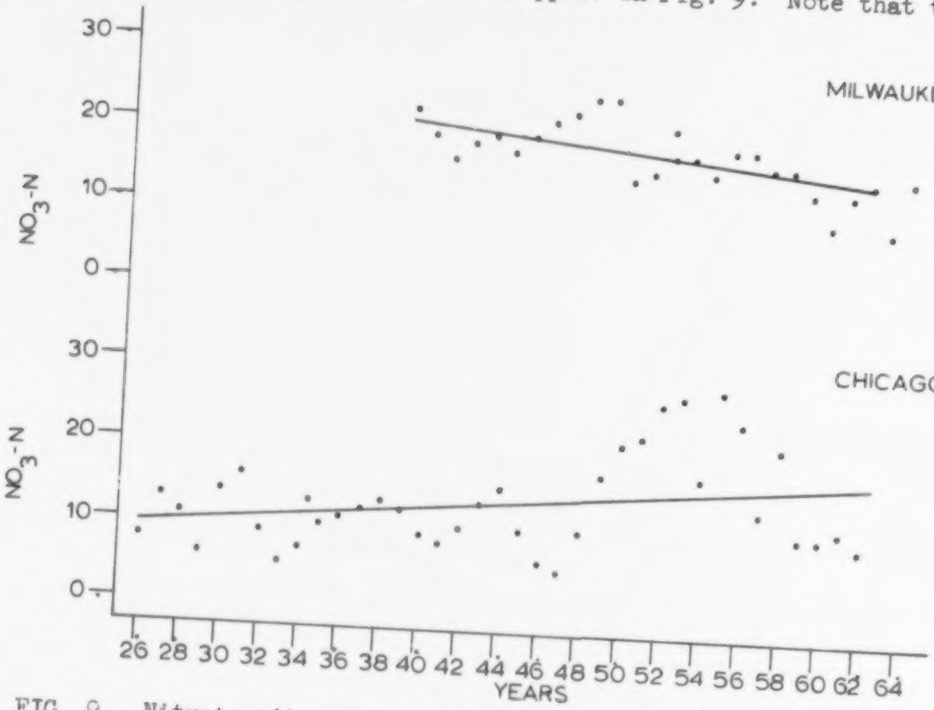


FIG. 9. Nitrate-nitrogen vs. time at Milwaukee and Chicago.

Yearly averages of nitrate-nitrogen at Michigan City and Whiting are considerably higher than those from Chicago and Milwaukee. From 1957 through 1964 average yearly nitrate-nitrogen values at Chicago and Milwaukee ranged between 0.08 and 0.21 ppm; those at Michigan City and Whiting ranged between 0.22 and 0.52 ppm, and minimum levels at the latter two places were for the most part near 0.30 ppm.

Phosphorus was measured only at Chicago prior to 1964. Since then it has also been included in the analysis routine at Michigan City and Whiting. At Chicago phosphorus determination was initiated shortly after the change to the South District Filtration Plant laboratory in 1948. Orthophosphate was first determined in December 1949, and has been continued to the present. Total phosphate measurements were begun in September 1961 following the 11th edition of *Standard Methods* (APHA 1960).

The methodology used in the orthophosphate analysis at Chicago has been changed several times. The initial determinations were based on a method described in the *Cenco Technical Bulletin*. In April 1956, Method C from the 10th edition of *Standard Methods* was adopted, and in June 1961, was replaced by Method B of the 11th edition. The three techniques are all essentially the same, the principal changes being toward greater accuracy and precision. The method adopted in 1961 specifies a minimum detectable level of 0.01 mg/l $PO_4$; this is the lowest level that has been reported by the Chicago laboratory since the change to *Standard Methods* in 1956. Lesser concentrations are reported simply as <0.01 mg/l. Between 1949 and 1956, however, levels considerably lower than this, and none higher, were reported, and it is doubtful that the Cenco method offered greater sensitivity than those given in *Standard Methods*. The results reported prior to April 1956 must be considered questionable, and have not been used here. Orthophosphate is reported by the Chicago laboratory as mg/l $PO_4$; it has been converted for use in the present study to parts per billion $P(P = PO_4 \times 0.326)$. By this conversion, the minimum detectable level of 0.01 mg/l $PO_4$ is equivalent to 3 ppb P.

Figure 10 shows the levels of orthophosphate-phosphorus and total phosphorus as measured on water from the Dunne, Dever, and Wilson cribs from 1956 through 1964. The data are plotted with respect to the individual months in each year that analyses were made, rather than as yearly averages which would be relatively meaningless.

Since April 1956, the majority of the orthophosphate-phosphorus values at Chicago have not exceeded 5 ppb: most fell in the range 3 to 5 ppb, which probably is the "normal" range for the inshore Chicago region. On some occasions much higher, "abnormal," levels were reported from one or more of the intakes; they are summarized in Table 2. From the table it can be seen that unusually high phosphorus levels are not a seasonal phenomenon, and they are not necessarily observed, when they do occur, at all of the intakes.

Phosphorous measurements at Michigan City and Whiting are for total soluble phosphates. The method used is essentially the stannous chloride method for total

TABLE 2. Occurrence of "abnormal" orthophosphate-phosphorus levels at the Chicago intakes, 1956-64, with corresponding total phosphorus levels, available.

| Year | Month | Phosphorus, ppb | | | | | |
|---|---|---|---|---|---|---|---|
| | | Dunne Crib plus SDFP shore intake | | Dever Crib | | Wilson Crib | |
| | | ortho | total | ortho | total | ortho | total |
| 1956 | April | 10 | | 10 | | 6 | |
| | August | | | | | 10 | |
| 1957 | January | 11 | | 10 | | 10 | |
| 1958 | July | 12 | | | | | |
| 1961 | June | 16 | | 13 | | 10 | |
| | September | 10 | 16 | 13 | 26 | 16 | 29 |
| 1962 | February | | | | | 16 | 16 |
| | June | 7 | 20 | | | 13 | 52 |
| | November | | | | | 6 | 20 |
| 1963 | February | 6 | 26 | 10 | 33 | 10 | 20 |
| | May | | | 6 | 36 | 6 | 16 |
| | August | | | | | | |
| 1964 | August | (no "abnormal" levels) | | | | | |

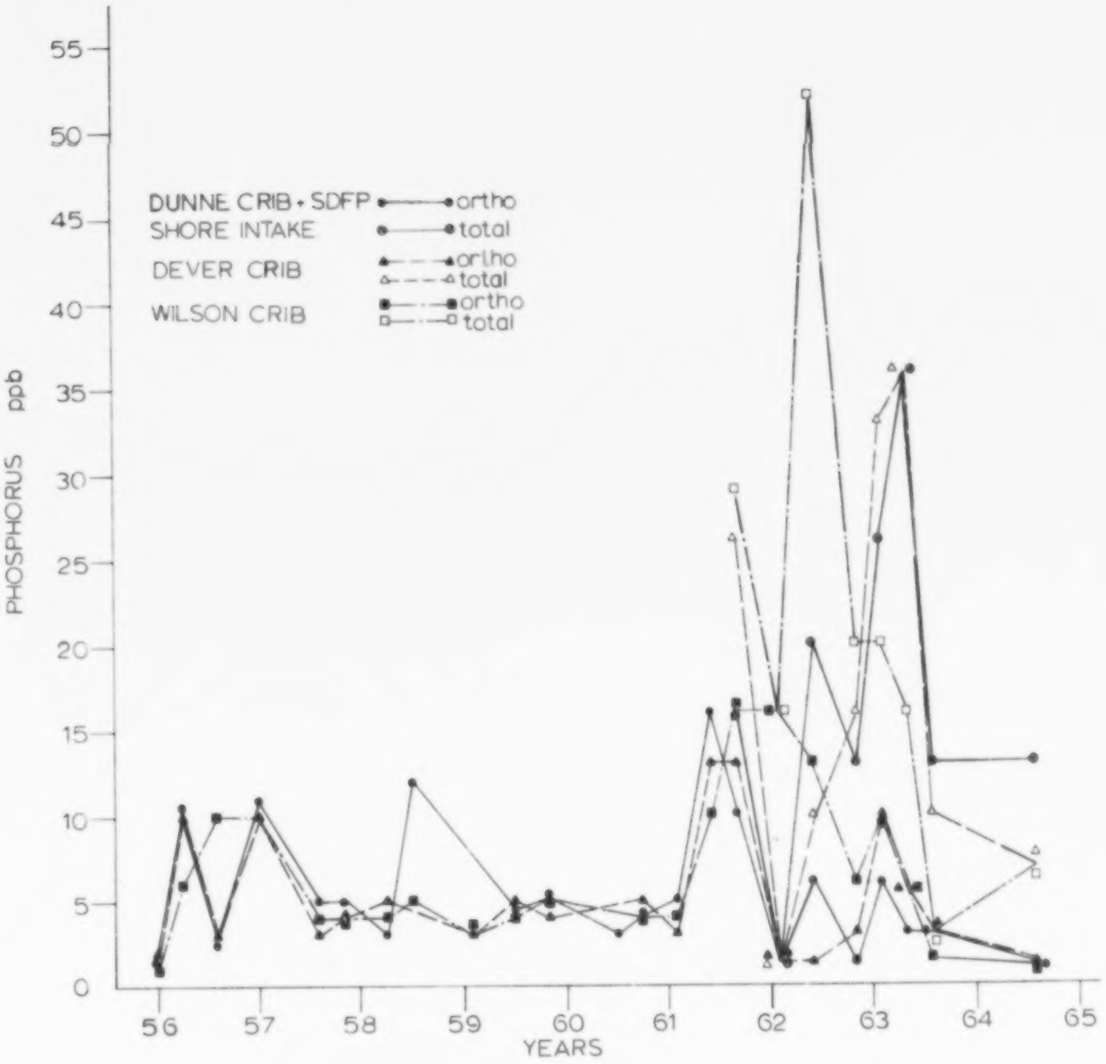


FIG. 10. Phosphorus vs. time at Chicago.

phosphates found in the 11th edition of Standard Methods. Results from these two plants for the year 1964 have been used in the present study. Samples for phosphorous determination are taken about twice each month throughout the year. Results are reported as mg/l $PO_4$. In the present report these have been converted to ppb P as was done for the Chicago data. Average phosphorus for the entire year 1964 was considerably higher at Michigan City than at Whiting. The average for Michigan City (excluding one extremely high value for August) was 0.09 mg/l $PO_4$-P, or 90 ppb P. The average for Whiting was 0.06 mg/l $PO_4$-P, or 60 ppb P. Levels at Michigan City ranged from 0.0 in December to 3260 ppb $PO_4$-P in August; discounting these two extremes, the range was from 33 to 424 ppb. At Whiting the range was 0.0 to 196 ppb. At Michigan City the levels of 424 ppb in February and 3260 ppb in August represented unusual highs similar to those noted at irregular intervals at Chicago. A level of 163 ppb in January and one of 196 ppb in August may represent similar "abnormal" highs at Whiting.

## COMPARATIVE DATA FROM THE OPEN LAKE

In order to ascertain whether conclusions based on analysis of data from near shore can be extended to embrace conditions in the open lake, it is necessary to determine, as nearly as possible, how closely the nearshore conditions approximate those existing farther out in the lake. One must know, within reasonable limits, whether conditions as hind-cast from serial historical measurements performed on intake water can be confidently utilized in the assessment of past water quality conditions and the prediction of probable future conditions.

Data obtained by the Great Lakes Research Division between 1961 and 1966 and those published by Risley and Fuller (1965) have been used as indices of open-lake conditions. Data collected by the Division were in the following years and locations:

1961: Vicinity of the Grand Rapids, Chicago, and Milwaukee intakes.

1962: Four reference stations at the following positions:

Station R-1: 41°51.3', 87°29.5'
Station R-2: 42°00.7', 87°17.0'
Station R-3: 42°17.0', 86°58.8'
Station R-4: 42°33.6', 86°52.2'

These stations were positioned roughly along the median axis of the lake. R-1 was about 6 miles off the Chicago waterfront, and the remaining three stations about equally spaced between that location and the deepest part of the southern basin in midlake between Holland and Racine. Water samples were obtained by Nansen bottle from four depths: surface, the lower part of the epilimnion, the upper part of the hypolimnion, and near bottom.

1963: As for 1962.

1964: Four transects located as follows:

Transect A: between Benton Harbor and Chicago. Stations A-4 and A-6 occupied approximately the same positions as stations R-1 and R-2.

Transect B: between South Haven, Mich. and Waukegan, Ill. Station B-4 corresponds approximately to R-3.

Transect C: between Holland, Mich., and Racine, Wis. Station C-5 corresponds approximately to R-4.

Transect D: between Ludington, Mich. and Sheboygan, Wis.

A fifth transect, between Frankfort, Mich., and Kewaunee, Wis., also existed during 1964 but is north of the area being considered here. Three chemistry stations were established on each transect, for a total of 12. One chemistry station on each transect was in midlake, and two others, one near each end, were about 10 miles from shore. Water samples were obtained by Nansen bottle from the surface, 20 m, 1/4 the distance between 25 m and the bottom, and 3/4 the distance between 25 m and the bottom.

1965-66: The four transects described for 1964. Total dissolved solids data were obtained from these transects during 1965 and 1966, but not during 1964.

The data of Risley and Fuller (1965) were collected in 1962 and 1963 on four transects: Calumet Harbor to Michigan City, Chicago to New Buffalo, Glencoe to Benton Harbor, and Sheboygan to Little Sable Point, Mich. Their study plan was, in general, to carry out intensive sampling of the extreme south end of the lake, and to compare results there with conditions in the northern part as represented by the Sheboygan to Little Sable Point transect.

The data obtained from the different stations and transects are presented, as averages and ranges for all depths in Table 3. Data from the 1964-66 Great Lakes Research Division transects are given as averages of transects A, B, and C as the best expression of the entire southern basin; as averages of transects A and B to represent the southern half of the southern basin; and as averages of transects C and D to represent the more northerly portion of the area of interest, including the Milwaukee region.

## COMPARISON OF NEARSHORE AND OPEN LAKE DATA

### SULFATE

Sulfate in the open lake exhibits little variation geographically or with depth at any given time. Both our own data and that of Risley and Fuller show no tendency toward a north-south gradient of sulfate in the lake. The average for our transects A and B was 16.5 ppm, and for C and D, 16.0. The range of values was nearly the same in both cases, also: 12.0 to 21.5 and 12.5 to 22.5, respectively. In their three southern transects, Risley and Fuller obtained average sulfate values of 22.0, 20.0, and 22.0, and for the northern transect between Sheboygan and Little Sable Point, 21.0. Their average values are some-

TABLE 3. Summary of open-lake chemical data for Lake Michigan, 1961-64.

| Data Source | Year | Months | Stations | Average (ppm) | Range (ppm) |
|---|---|---|---|---|---|
| | | | Sulfate | | |
| G.L.R.D. | 1961 | July | Grand Rapids intake vic. | 17.5 | 15.0-20.0 |
| | | July | Chicago intake vic. | 18.0 | 15.5-27.0 |
| | | Aug | Milwaukee intake vic. | 20.0 | 18.0-29.0 |
| | 1962 | Aug-Oct | R-1 | 16.5 | 15.5-18.5 |
| | | Aug-Oct | R-2 | 16.0 | 14.5-19.0 |
| | | Aug-Oct | R-3 | 16.0 | 14.5-18.0 |
| | | Aug-Oct | R-4 | 15.5 | 14.5-18.0 |
| | 1963 | No Data | | | |
| | 1964 | Apr-Nov | Avg, transects A + B + C | 16.5 | 12.0-22.0 |
| | | Apr-Nov | Avg, transects A + B | 16.5 | 12.0-21.5 |
| | | Apr-Nov | Avg, transects C + D | 16.0 | 12.5-22.5 |
| Risley & Fuller | 1962-63 | --- | Calumet Hbr - Mich City | 22.0 | 15.0-57.0 |
| | | --- | Chicago - New Buffalo | 20.0 | 12.0-28.0 |
| | | --- | Glencoe - Bent Hbr | 22.0 | 12.0-40.0 |
| | | --- | Sheboygan - L Sable Pt | 21.0 | 10.0-49.0 |

TABLE 3. (Continued)

| Data Source | Year | Months | Stations | Average (ppm) | Range (ppm) |
|---|---|---|---|---|---|
| | | | Chloride | | |
| G.L.R.D. | 1961 | July | Grand Rapids intake vic. | 5.8 | 4.8- 7.6 |
| | | July | Chicago intake vic. | 7.3 | 6.2- 8.2 |
| | | Aug | Milwaukee intake vic. | 7.9 | 6.6-11.2 |
| | 1962 | Aug-Oct | R-1 | 6.1 | 4.6- 8.7 |
| | | Aug-Oct | R-2 | 5.5 | 4.3- 8.9 |
| | | Aug-Oct | R-3 | 5.3 | 3.8- 6.8 |
| | | Aug-Oct | R-4 | 5.4 | 4.5- 6.3 |
| | 1963 | Apr-Jun | R-1 | 6.5 | 6.3- 6.8 |
| | | Apr-Jun | R-2 | 5.9 | 5.7- 6.1 |
| | | Apr-Jun | R-3 | 5.7 | 5.6- 5.9 |
| | | Apr-Jun | R-4 | 5.7 | 5.6- 6.0 |
| | 1964 | No Data | | | |
| Risley & Fuller | 1962-63 | --- | Calumet Hbr - Mich City | 8.0 | 4.2-22.0 |
| | | --- | Chicago - New Buffalo | 6.6 | 4.4- 8.2 |
| | | --- | Glencoe - Bent Hbr | 7.3 | 5.3-18.0 |
| | | --- | Sheboygan - L Sable Pt | 6.6 | 5.4-10.0 |

TABLE 3. (Continued)

| Data Source | Year | Months | Stations | Average (ppm) | Range (ppm) |
|---|---|---|---|---|---|
| | | | Residue of Evaporation* | | |
| G.L.R.D. | 1961 | | No Data | | |
| | 1962 | Aug-Oct | R-1 | 158 | |
| | | Aug-Oct | R-2 | 150 | |
| | | Aug-Oct | R-3 | 154 | |
| | | Aug-Oct | R-4 | 149 | |
| | 1963 | | No Data | | |
| | 1964 | | No Data | | |
| | 1965 | Apr-Nov | Avg, transects A + B + C | 170 | |
| | | Apr-Nov | Avg, transects A + B | 170 | |
| | | Apr-Nov | Avg, transects C + D | 170 | |
| | 1966 | Mar-Jun | Avg, transects A + B + C | 154 | |
| | | Mar-Jun | Avg, transects A + B | 156 | |
| | | Mar-Jun | Avg, transects C + D | 155 | |
| Risley & Fuller | 1962-63 | | No Data | | |

*Data for residue on evaporation not available for 1964, but were taken in 1965 and 1966.

TABLE 3. (Continued)

| Data Source | Year | Months | Stations | Average (ppm) | Range (ppm) |
|---|---|---|---|---|---|
| | | | **Nitrate-Nitrogen** | | |
| G.L.R.D. | 1961 | No Data | | | |
| | 1962 | Aug-Oct | R-1 | 0.06 | 0.00-0.14 |
| | | Aug-Oct | R-2 | 0.14 | 0.03-0.27 |
| | | Aug-Oct | R-3 | 0.14 | 0.02-0.30 |
| | | Aug-Oct | R-4 | 0.12 | 0.00-0.22 |
| | 1963 | Apr-Jun | R-1 | 0.09 | 0.04-0.14 |
| | | Apr-Jun | R-2 | 0.13 | 0.08-0.17 |
| | | Apr-Jun | R-3 | 0.14 | 0.07-0.22 |
| | | Apr-Jun | R-4 | 0.13 | 0.01-0.19 |
| | 1964 | Apr-Nov | Avg, transects A + B + C | 0.09 | 0.00-0.36 |
| | | Apr-Nov | Avg, transects A + B | 0.10 | 0.00-0.25 |
| | | Apr-Nov | Avg, transects C + D | 0.07 | 0.00-0.36 |
| Risley & Fuller | 1962-63 | --- | Calumet Hbr - Mich City | 0.12 | 0.00-0.84 |
| | | --- | Chicago - New Buffalo | 0.09 | 0.01-0.38 |
| | | --- | Glencoe - Bent Hbr | 0.10 | 0.01-0.29 |
| | | --- | Sheboygan - L Sable Pt | 0.19 | 0.02-0.27 |

TABLE 3. (Concluded)

| Data Source | Year | Months | Stations | Average (ppb) | Range (ppb) |
|---|---|---|---|---|---|
| | | | Total Phosphorus | | |
| G.L.R.D. | 1961 | No Data | | | |
| | 1962 | No Data | | | |
| | 1963 | No Data | | | |
| | 1964 | Apr-Nov | Avg, transects A + B + C | 6.1 | 0- 49.0 |
| | | Apr-Nov | Avg, transects A + B | 5.4 | 0- 47.7 |
| | | Apr-Nov | Avg, transects C + D | 6.4 | 0- 49.0 |
| Risley & Fuller | 1962-63 | --- | Calumet Hbr - Mich City | 20.0 | 0-185.0 |
| | | --- | Chicago - New Buffalo | 13.0 | 0- 94.0 |
| | | --- | Glencoe - Bent Hbr | 6.0 | 0- 52.0 |
| | | --- | Sheboygan - L Sable Pt | 6.0 | 0- 26.0 |

what higher than those obtained by us, but the north-south uniformity is shown by both sets of data. Their higher averages are reflected in the greater range of values in their data, and are probably due to a higher incidence of samples taken quite near shore. Our 1961 data, taken near shore in the vicinities of the Grand Rapids, Chicago, and Milwaukee intakes, indicate that sulfate levels tend to be higher near shore than in the open lake. Average values in the area of the intakes were between 17.5 and 20.0 ppm, with an overall range of 15.0 to 29.0 ppm. Highest sulfate levels were at Milwaukee and the lowest at Grand Rapids. These averages and ranges are greater than those from stations R-1, 2, 3, and 4 in 1962 and from transects A, B, C, and D in 1964.

The average sulfate level for the open lake, as indicated by our 1962 and 1964 data, is very nearly 16 ppm. This is less than the average level found by any of the three filtration plants. Reading from the long-term regressions, the approximate sulfate level at Grand Rapids in 1961 was 28 ppm, and at Chicago in 1962 about 18.5 ppm. At Milwaukee, using the 1948-62 regression, the indicated level for 1962 is a little less than 19 ppm. The Milwaukee and Chicago values are in very good agreement with the open-lake averages, but the indicated sulfate level for Grand Rapids, 28 ppm, is much higher than shown by opne-lake data, and also much higher than values found during our 1961 studies around the Grand Rapids intake. It will also be noted, from the diagram of sulfate vs. time at Grand Rapids (Fig. 3) that sulfate trends there have been quite irregular when compared to those at Milwaukee and Chicago; the degree of scatter is great. For some reason, then, possibly its proximity to the large rivers which enter the eastern side of the southern basin, sulfate values as measured from the Grand Rapids intake water are variable and generally high, and are not representative of known sulfate concentrations occurring in the open lake.

## CHLORIDE

The distribution of chloride in the open lake is similar in its characteristics to that of sulfate. There does seem to be some indication that chloride levels may be slightly higher in the southern part of the lake, but the gradients are small. In both 1962 and 1963 we found higher average chloride levels at station R-1 near Chicago than at stations R-2, 3, and 4 located farther from shore and extending north up the center of the lake. Risley and Fuller found the highest average chloride levels on their southernmost transect, that lying between Calumet Harbor and Michigan City. Chloride there averaged 8.0 ppm, and ranged from 4.2 to 22.0 ppm. The latter figure is quite high for Lake Michigan. However, their Chicago-New Buffalo transect exhibited the lowest average chloride value and the lowest range encountered, even though two other transects occupied more northerly locations (see Table 3). No chloride data were obtained at our 1964 transects, which would have been more strictly comparable with the measurements of Risley and Fuller than the data from our 1961-62 reference stations. Our 1961 measurements, made in the immediate vicinity of the filtration plant intakes, show higher average values for the Chicago and Milwaukee regions than were obtained during the two following years in the open lake. The average in the Chicago region was 7.5, and at Milwaukee 7.9. Interestingly enough, the average chloride levels in the region of the Grand Rapids intake were the lowest found, 5.8 ppm.

From our own data and that of Risley and Fuller one can set the general average chloride level of the lake at about 5 to 7 ppm, with higher values occurring in the extreme south end and in certain nearshore localities. The 1961 level at Grand Rapids and the 1962 levels at Chicago and Milwaukee all fall within this range. The levels indicated by the regressions are as follows:

Grand Rapids, 1961: 6.8 ppm
Chicago, 1962: 6.8 ppm
Milwaukee, 1962: 6.5 ppm

Data for 1963 and 1964 have been obtained for Chicago and Milwaukee, and were shown in Fig. 5 along with data from Michigan City and Whiting. The average 1964 chloride level at Chicago was unusually high. Through the period 1957-1964 values at Whiting were for the most part higher than at the remaining four localities, except for the 1964 Chicago average. Chloride at Michigan City was consistently lower than at Whiting, and tended to be nearer the extreme south end average, found by Risley and Fuller, of 8.0 ppm.

## TOTAL SOLIDS (RESIDUE ON EVAPORATION)

Residue on evaporation was measured at our reference stations in 1962, and at the chemical stations on our transects in 1965 and 1966. The 1962 determinations are for total residue on evaporation, whereas those for 1965 and 1966 are for filterable residue. The water on which the 1962 analyses were performed was not filtered; analyses from 1965 and 1966 were carried out on water which had been passed through a 0.8μ membrane filter.

The results from the 1962 reference stations agree well with those from the transect stations in 1966. Results from 1965 are about 15 ppm higher than those of 1966. The 1965 observations covered a longer time period, April through November, than did those for 1966, which were for the period March through June, but it is not possible to say whether this was responsible for the higher average values found in 1965. It is probably more likely that there was some systematic difference in the analysis routine followed for the two years.

The total solids levels as indicated by the regressions for Grand Rapids, Chicago, and Milwaukee are as follows:

Grand Rapids, 1961: 1[illegible]8 ppm
Chicago, 1962: 163 ppm
Milwaukee, 1962: 155 ppm

These values, when compared with the open-lake values from 1962, 1965, and 1966, show the indicated levels at Grand Rapids to be higher than would be expected, but that total solids as observed at Chicago and Milwaukee agree well with open-lake measurements. Chicago, with 163 ppm, is above the 150-160 ppm open-lake range for 1962 and 1966, but is below the 170 average found in 1965. Total solids levels at Michigan City and Whiting (Fig. 7(b)) were seen to be consistently higher than even those at Grand Rapids, and quite a bit higher than average open-lake values. The overall range for these two localities for the period 1957-64 was 172 to 209 ppm. In view of the findings of Risley and Fuller with respect to various chemical parameters in that region, however, it is possible that these high values are truly representative of the extreme southern end of Lake Michigan.

## SILICA

Data on the occurrence of silica in Lake Michigan have been obtained from Ayers *et al*. (1958). Determinations were made on surface and subsurface samples obtained during two synoptic surveys of the entire lake carried out on 9 and 10 August 1955. Two gradients are observable in the southern basin from their data (see Ayers *et al*. 1958, Figs. 33 and 46). The principal gradient, noted on both days, was north-south, with values decreasing from a high off Milwaukee to a low in the region off Chicago. The highest silica values found in the southern basin on those dates were near the east shore; this condition was particularly pronounced on 9 August.

Since the quantity of comparative open-lake data is limited, no attempt has been made here to compare numerically the intake data with that from Ayers *et al*. However, the pattern of distribution found by them agrees with the comparative magnitudes of silica as observed at the plants. 1961-62 levels at Grand Rapids and Milwaukee are about 4 ppm, whereas at Chicago they are about 1.5 to 2 ppm. This corresponds with the north-south gradient observed during the 1955 synoptics, when silica levels off Chicago were less than those farther north in the Grand Rapids and Milwaukee regions.

## NITROGEN

Nitrate-nitrogen values for the open lake, as obtained by use in 1962, 1963, and 1964 and by Risley and Fuller in 1962-63 are all in substantially good agreement. Average values do not vary greatly from one-tenth part per million, although the ranges are relatively great, from zero to as much as 0.84 on the southermost transect of Risley and Fuller. Appreciable gradients along the axis of the lake are not indicated, although the highest average of Risley and Fuller occurred at their Sheboygan-Little Sable Point transect.

The considerable variability exhibited by nitrate-nitrogen at Chicago and Milwaukee makes difficult the comparison of this parameter as measured at those plants with measurements from off shore. It would be difficult for one to say, for instance, that the increase which occurred at Chicago between 1948 and 1955 actually took place throughout the southern part of the lake. The picture is further confused by the negative slope of the regression at Milwaukee as opposed to the positive slope at Chicago. The intercept of the Chicago regression with the year 1962 indicates a nitrate-nitrogen level of about 0.17 ppm. However, actual yearly averages for 1959-62 at Chicago (Fig. 9) have been approximately 0.10 ppm, and this is in good agreement with our data and that of Risley and Fuller for that part of the lake. The Milwaukee regression indicates a nitrate value of about 0.14 for 1962. This is somewhat higher than our 1964 average of 0.07 ppm for transects C and D, but is in good agreement with reference station R-4, located in mid-lake about off Milwaukee.

Yearly averages of nitrate-nitrogen at Michigan City and Whiting, however, are considerably higher than average values from the open lake and those from Chicago and Milwaukee. With only two exceptions, yearly average nitrate-nitrogen at both Michigan City and Whiting has been 0.30 ppm or greater, with highs of 0.52 and 0.50 occurring at Michigan City in 1959 and 1963, respectively. The highest yearly average values for Whiting did not exceed 0.40 ppm. The degree to which indicated levels such as these are truly representative of the southern end of the lake is questionable. Risley and Fuller obtained values as high as 0.84 ppm in that region, but their average for the Calumet Harbor-Michigan City was only 0.12 ppm.

## PHOSPHORUS

Total phosphorus measurements representative of the open lake are available from our 1964 transects and from the data of Risley and Fuller. Little variation was noted among results from our several transects, as is evident from the data summary in Table 4. The average of transects A, B, and C was 6.1 ppb total-P; of A and B, 5.4 ppb; and of C and D, 6.4 ppb. This agrees well with Risley and Fuller, who found average values of 6.0 ppb on their Glencoe-Benton Harbor and Sheboygan-Little Sable Point transects. The average levels of total phosphorus on their two southernmost transects were higher than this; the average for the Chicago-New Buffalo transect was 13.0 ppb, and for the Calumet Harbor-Michigan City transect, in the extreme southern end of the lake, it was 20.0 ppb. The range of values for this latter transect was much higher than from any of their other transects or from our own, attaining levels up to 185 ppb. The average levels of total phosphorous at Michigan City and Whiting are within this range: Michigan City's 1964 average was 90 ppb, and Whiting's 60 ppb.

The marked fluctuations in phosphorus levels as measured at Chicago (Fig. 10) do not reflect any consistent trend toward a buildup of phosphorus in the lake. It seems more likely that the nonperiodic highs and lows are reflections of the passage of localized water masses past the intakes, and that a given individual water mass does not necessarily traverse all the functional intakes. The value of nearshore phosphorus measurements as indicators of water quality trends is doubtful, since this parameter in particular appears subject to local disturbances which are not at all necessarily related to overall conditions in any given area of the lake.

## DISCUSSION

Measurements of the quantities of various chemical substances occurring in the water of Lake Michigan have been carried out for varying time intervals at the filtration plants serving Grand Rapids, Chicago, and Milwaukee. Continuous records at Chicago extend back to 1926, at Milwaukee to 1939, and at Grand Rapids to 1941. It is evident from the year-to-year average increases in the concentration of many of these substances that a progressive accumulation of certain materials is occurring in the lake water in the region of the intakes. Comparison of the levels of calcium, chloride, sulfate, total solids, silica, nitrogen, and phosphorus occurring in lake water obtained through the plant intakes with levels of these same substances measured in open-lake water shows that data on these parameters from Chicago and Milwaukee are closely comparable with like data from the open lake. Certain of the data from Grand Rapids, however, primarily sulfate and total solids, are more at variance with open-lake measurements. Average values of the above parameters from Grand Rapids in 1961, and Chicago, Milwaukee, Michigan City, and Whiting in 1962, along with comparative open-lake values, are summarized in Table 4. Although certain data from some locations through 1964 are in hand and have been discussed earlier in this report, they are not included in the table.

Overall, the agreement between plant values and those from the open lake is surprisingly good. Calcium at Chicago agrees precisely with the approximate average for the lake found by Ayers _et_ _al_. (1958), while Grand Rapids and Milwaukee are a bit higher with values of 36 and 34.5 ppm, respectively. Grand Rapids, Chicago, and Milwaukee all agree closely with Beeton and Chandler's value for magnesium in Lake Michigan, 10.4 ppm. All three plants, on the other hand, yield average sulfate levels which are higher than the approximate open-lake average of 16 ppm. Grand Rapids, whose 1961 average was in the neighborhood of 28-29 ppm, shows the greatest discrepancy with respect to open-lake measurements. Milwaukee and Chicago both show 1962 average levels of about 19 ppm, much nearer the open-lake estimate. They are in very good agreement with the average values cited by Risley and Fuller. All three plants are quite near the open-lake average for chloride, as also are Michigan City and Whiting. Open-lake values are in the range 5 to 7 ppm, and averages from the plants are between 6.5 and 8, the highest being at Whiting. Chicago and Milwaukee exhibit the closest correspondence with open-lake total solids and dissolved solids content, although the Grand Rapids 1961 average of 178 ppm is not greatly at variance with our 1965 average from transects A, B, C, and D, of 170 ppm. However, the evidence of our data from 1962 and 1966 and Beeton's (1965) value of about 150 ppm dissolved solids for Lake Michigan lead one to believe that our 1965 average of 170 ppm dissolved solids is too high. The average of 155 ppm obtained in 1966 appears much more realistic. Grand Rapids is more than 20 ppm above this latter figure.

TABLE 4. Approximate average values of various chemical parameters, for the years indicated, for Grand Rapids, Chicago, Milwaukee, Michigan City, Whiting, and the open lake. Values are in parts per million (ppm) except for phosphorus, which is given as parts per billion (ppb).

| Parameter | Grand Rapids 1961 | Chicago 1962 | Milwaukee 1962 | Michigan City 1962 | Whiting 1962 | Open Lake |
|---|---|---|---|---|---|---|
| Calcium | 36 | 32 | 34.5 | --- | --- | approx 32* |
| Magnesium | 11 | 10.5 | 11 | --- | --- | 10.4** |
| Sulfate | 28-29 | 18-20 | 19 | --- | --- | 16 |
| Chloride | 7 | 7 | 6.5 | 6.5 | 8 | 5-7 |
| Total solids | 178 | 163 | 155 | 191 | 183 | 1962, 153; 1965, 170; 1966, 155 |
| Silica | 4 | 1.5 | 4 | --- | --- | 1955, 0.6-3.6 |
| Nitrate-N | --- | 0.10 | 0.15 | 0.37 | 0.34 | approx 0.10 |
| Orthophosphate | (averages not computed) | | | | | no data |
| Total phosphorus | (averages not computed) | | | | | approx 6, north of Chi-New Buff.<br>13-20, south of Chi-New Buff. |

*From Ayers et al. (1958).

**From Beeton and Chandler (1963).

Total solids values from Michigan City and Whiting are considerably greater than any others. The 1962 average for Michigan City is 191 ppm, and that for Whiting, 183 ppm. This is probably a reflection of both intake location (discussed earlier) and the extreme south end locale of those plants. No total solids or dissolved solids data exist for the open lake in that sector, and so evaluation of these data from the two latter plants cannot be properly attempted. Considering once again, however, the high levels of the various chemical parameters found in the southern tip of the lake by Risley and Fuller, the elevated values for solids indicated at Michigan City and Whiting are likely, in part, actual commentaries on the existing water quality.

With respect to silica, Grand Rapids and Milwaukee values for 1961 and 1962, respectively, are in agreement at 4 ppm, while Chicago is much lower with 1.5 ppm. As pointed out earlier, however, this is in agreement with the distribution found by Ayers et al. in 1955, when silica values in the south end of the lake were much lower than elsewhere. Beeton and Chandler (1963) give an average silica content for Lake Michigan of 3.1 ppm, a figure in good agreement with the other silica data presented here.

Nitrate-nitrogen at Chicago and Milwaukee agrees quite well with open-lake values, while Michigan City and Whiting are much higher. Phosphorus from Chicago, Michigan City, and Whiting were found to be higher than those obtained from adjacent parts of the open lake.

The favorable comparisons of the filtration plant data with that available from the open lake lends confidence to the use of such nearshore data in the evaluation of water quality and trophic changes in Lake Michigan. A similar study conducted in Lake Erie (Powers et al. 1960) resulted in the application of similar confidence to the accumulated data of certain filtration plants there, and it can therefore probably be assumed that careful selection and analysis of onshore data sources in other lakes would likewise result in bodies of information useful in assessing trends associated with environmental changes.

The changes which have occurred in the levels of the several parameters considered in the assessment of the Grand Rapids, Chicago, and Milwaukee plants over their periods of record are summarized in Table 5.

TABLE 5. Changes in average values of various parameters, as indicated by computed regressions, over indicated periods of record.

| Parameter | Chicago | | Milwaukee | | Grand Rapids | |
|---|---|---|---|---|---|---|
| | 1926-62 | 1948-62 | 1939-62 | 1948-62 | 1941-61 | 1948-61 |
| Calcium | 33.4-32.3 | 33.6-31.9 | 34.4-34.5 | 34.4-34.5 | 35.5-36.0 | 35.9-35.9 |
| Magnesium | 10.9-10.4 | 10.8-10.2 | 10.6-11.3 | 11.1-11.1 | 10.6-11.1 | 10.9-11.0 |
| Sulfate | 13.8-18.6 | 15.8-20.6 | 17.7-17.7 | 16.2-18.8 | 18.9-27.8 | 19.1 -29.4 |
| Chloride | 3.8-6.8 | 5.6-7.3 | 3.0-6.5 | 4.2-6.5 | 4.8-6.8 | 5.1-7.2 |
| Total solids | 159-163 | ----- | 148-154.5 | ----- | 163-178 | ----- |
| Silica | 4.8-1.5 | 2.5-1.6 | 6.0-4.[illegible] | 7.7-3.0 | 7.2-4.7 | 8.1-3.5 |
| Nitrate-N | 0.10-0.17 | ----- | 0.205-0.14 | ----- | ------ | ----- |

Ownbey and Willeke (1965) have calculated the probable buildup of chloride and sulfate in Lake Michigan, and have projected the concentrations of these ions in the lake for the years 1980, 2000, and 2020. Extrapolation of the regressions on these two parameters for Chicago and Milwaukee yields excellent agreement with their calculated rates of increase:

| | Chloride | | Sulfate | |
|---|---|---|---|---|
| | 1980 | 2000 | 1980 | 2000 |
| Milwaukee | 9.3 | 12.5 | 22.0 | 25.7 |
| Chicago | 8.3 | 10.0 | 21.0 | 23.6 |
| Ownbey and Willeke | 7.9 | 9.6 | 21.8 | 24.7 |

In the case of chloride, the Chicago data agree more closely with Ownbey and Willeke; with sulfate, it is Milwaukee. Best results were obtained by extrapolation of the regression line which describes the entire period of record, except in the case of Milwaukee sulfate, where the essentially horizontal regression appears to be the less realistic.

While, as Ownbey and Willeke state, the presence of increased quantities of chloride, and sulfate in amounts such as shown above may not in themselves be of significance in environmental alterations, the very fact that they are increasing is an indication that other chemicals and solid materials are likewise increasing in concentration within the lake, and the buildup of certain of these other materials in Lake Michigan has been demonstrated here. From the chemical standpoint, then, it is clear that the lake is undergoing environmental change, and biological ramifications of this are already evident. For example, Robertson and Alley (1966) have shown that the total quantity of macrobenthos in the lake has increased significantly in the lake since the early 1930's; Powers and Robertson (1965) have shown that oligochaetes predominate over amphipods (otherwise the most numerous macrobenthic organism in the lake) in the south end of the lake; the U. S. Public Health Service (1965) and unpublished data of the Great Lakes Research Division have shown that the benthic fauna of the extreme south end of the lake have been adversely affected by deleterious environmental changes resulting from industrial pollution; and Damann (1966) has demonstrated that total plankton at Chicago increased significantly over the period 1926-58. These are but some of the biological changes that have been shown to have occurred within the lake, and are most probably associated with the environmental alteration which is evident in the long-term change in concentrations of ions and other solids.

# REFERENCES

AMERICAN PUBLIC HEALTH ASSOCIATION. 1960. Standard methods for the examination of water and wastewater, eleventh edition. Amer. Pub. Health Assoc., Inc., New York.

AYERS, JOHN C. 1965. The climatology of Lake Michigan. Pub. No. 12, Great Lakes Res. Div., Univ. of Mich., 73 p.

__________, DAVID C. CHANDLER, GEORGE H. LAUFF, CHARLES F. POWERS, and E. BENNETTE HENSON. 1958. Currents and water masses of Lake Michigan. Pub. No. 3, Great Lakes Res. Div., Univ. of Mich., 169 p.

BEETON, ALFRED M. 1965. Eutrophication of the St. Lawrence Great Lakes. Limnol. and Oceanog. 10(2): 240-254.

__________. 1966. Indices of Great Lakes eutrophication. Pub. No. 15, Great Lakes Res. Div., Univ. of Mich., p. 1-8.

__________, and DAVID C. CHANDLER. 1963. The St. Lawrence Great Lakes. In Limnology in North America, David G. Frey, Ed., p. 535-558.

DAMANN, KENNETH E. 1960. Plankton studies of Lake Michigan. II. Thirty-three years of continuous plankton and coliform bacteria data collected from Lake Michigan at Chicago, Illinois. Trans. Amer. Microscop. Soc., LXXIX (4): 397-404.

OWNBEY, C. R., and G. E. WILLEKE. 1965. Long-term solids buildup in Lake Michigan water. Pub. No. 13, Great Lakes Res. Div., Univ. of Mich., p. 141-152.

POWERS, CHARLES F., DAVID L. JONES, and JOHN C. AYERS. 1959. Sources of hydrographic and meteorological data on the Great Lakes. U. S. Fish and Wildlife Serv., Spec. Sci. Rpt. - Fish. No. 314, 183 p.

__________, __________, PAUL C. MUNDINGER, and JOHN C. AYERS. 1960. Applications of data collected along shore to conditions in Lake Erie. Pub. No. 5, Great Lakes Res. Div., Univ. of Mich., 78 p.

__________, and ANDREW ROBERTSON. 1965. Some quantitative aspects of the macrobenthos of Lake Michigan. Pub. No. 13, Great Lakes Res. Div., Univ. of Mich., p. 153-159.

RISLEY, CLIFFORD, JR., and FREDERIC D. FULLER. 1965. Chemical characteristics of Lake Michigan. Pub. No. 13, Great Lakes Res. Div., Univ. of Mich., p. 168-174.

ROBERTSON, ANDREW, and WAYNE P. ALLEY. 1966. A comparative study of Lake Michigan macrobenthos. Limnol. and Oceanog. 11(4): 576-583.

U. S. PUBLIC HEALTH SERVICE. 1965. Report on pollution of the waters of the Grand Calumet River, Little Calumet River, Calumet River, Lake Michigan, Wolf Lake and their tributaries. U. S. Pub. Health Serv., Div. of Water Supply and Poll. Control, Region V, Chicago. Feb. 1965.

# LAKE MICHIGAN BIOLOGICAL DATA, 1964-66

Charles F. Powers, Andrew Robertson, Sharon A. Czaika, and Wayne P. Alley

## INTRODUCTION

The Lake Michigan Coherent-Area program was activated in September 1963, and field studies within the biological section were initiated in early spring of the following year. One of the major concepts underlying the biological investigations has been the evaluation of the standing crop of organic matter in the lake, with such fundamental information providing the means for further evaluating the Lake Michigan biological community in terms of its energenics, i.e., the cycling of organic matter through the various biological systems. It was immediately evident that large quantities of observations, in terms of both area and time, would be necessary, and a program was developed which would permit frequent sampling in the field as well as rapid laboratory analysis.

The data reported here are the routine biological data obtained between April 1964 and June 1966. Data relating to the benthos from April 1964 through July 1964 have not been included since sampling was conducted with the Petersen dredge which has subsequently been proven unreliable. Routine observations have been continued beyond June 1966, and will be included in subsequent reports.

The authors wish to acknowledge the valuable assistance of Kenneth L. Davidson in the computer programming, and of Jeanne Rose who assumed responsibility for much of the laboratory analysis.

## MEASUREMENTS

The biological program was designed to measure the quantities of organic matter present in the suspended particulate matter (phytoplankton plus detritus), zooplankton, macrobenthos, bottom sediments, and in the dissolved state. In view of the intensive sampling necessary to provide an adequate geographical and temporal picture of the distributions of these parameters, it was decided to express the organic content of the suspended particulate matter, zooplankton, and macrobenthos in terms of loss on ignition, since this type of analysis lends itself readily to rapid processing of large quantities of data. Dissolved organic matter and the organic matter contained in the sediments, on the other hand, cannot accurately be estimated through the loss on ignition technique, and "wet oxidation" methods were employed in the analysis of these quantities. These results have not been included here, and are being reported separately by Powers and Robertson (1967) and Robertson and Powers (1967). Further, these quantities were not measured on a monthly basis but have instead been studied from the seasonal aspect.

In addition to the above estimates involving various categories of organic matter within the lake, determinations of filterable residue on evaporation were carried out in 1965 and 1966 and are included in the present report.

## SAMPLING LOCATIONS

Thirty-five stations located on five cross-lake transects (plus two stations off Muskegon, Mich.) were designated as sampling locations (Fig. 1). These transects, proceeding from south to north, were designated transects

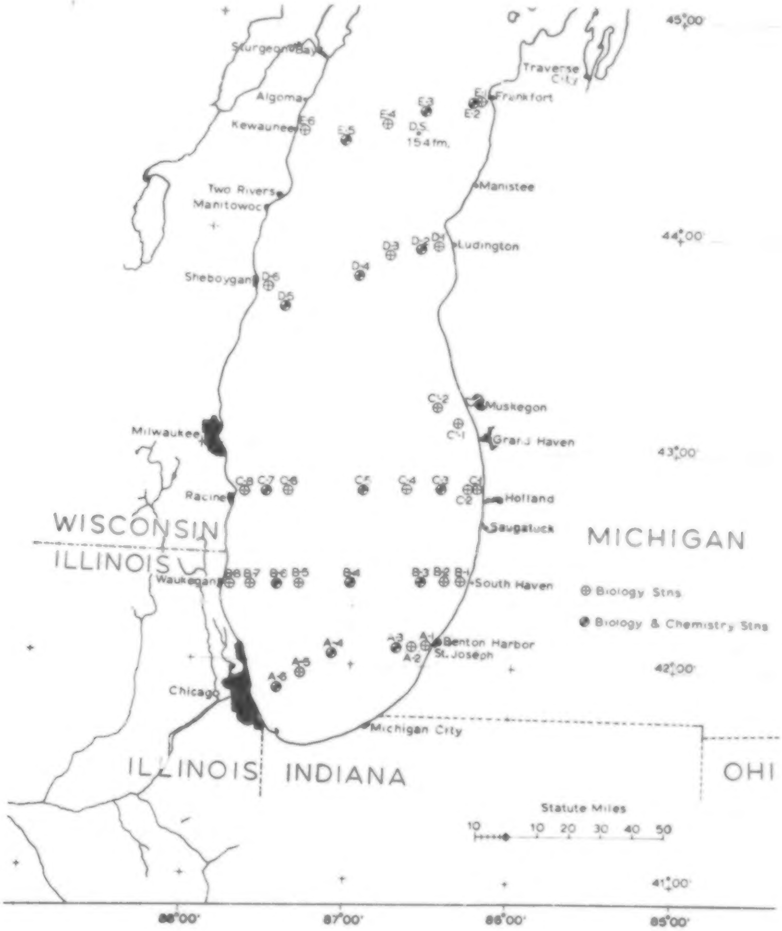

Sturgeon Bay
Algoma
Kewaunee
E6
E5
E4
E3
E2
E1
Frankfort
Traverse City
D.S. 154 fm.
Manistee
Two Rivers
Manitowoc
D3
D2
D1
Ludington
D4
Sheboygan
D6
D5
C12
Muskegon
C11
Grand Haven
Milwaukee
C8
C7
C6
C5
C4
C3
C1
C2
Holland
Racine
Saugatuck
WISCONSIN
ILLINOIS
MICHIGAN
B8
B7
B6
B5
B4
B3
B2
B1
Waukegan
South Haven
⊕ Biology Stns
● Biology & Chemistry Stns
A4
A3
A1
A2
Benton Harbor
St. Joseph
A5
A6
Chicago
Michigan City
ILLINOIS
INDIANA
OHI
Statute Miles
10 10 20 30 40 50
45°00'
44°00'
43°00'
42°00'
41°00'
88°00'
87°00'
86°00'
85°00'

FIG. 1. The transects of sampling stations in Lake Michigan.

A, B, C, D, and E. Stations on each transect were numbered serially from east to west. The two stations off Muskegon were designated C'-1 and C'-2. Transects A, B, and C were in the southern basin of the lake, and D and E were in the northern basin. Stations on A, B, and C were positioned primarily with respect to the major surficial bottom sediment types as described by Ayers and Hough (1964) for that part of the lake. Stations on lines D and E were positioned according to major bathymetric features, since detailed information on bottom types in that part of the lake was not available. Positions of certain stations were also influenced by the location of Eggleton's (1936) benthos sampling locations to facilitate comparison of presently existing benthic composition with that which existed in the early 1930's. These comparisons have been reported by Robertson and Alley (1966). The locations and depths of our stations are given in Table 1.

Three stations on each transect were designated as "complete" stations. At those stations, sampling was carried out for suspended particulate matter, zooplankton, macrobenthos, bottom sediment, dissolved organic matter, and filterable residue on evaporation. These stations were the following: A-3, 4, 6; B-3, 4, 6; C-3, 5, 7; D-2, 4, 5; and E-2, 3, 5. At the remaining stations, only macrobenthos and bottom sediments were sampled.

All stations were visited monthly throughout the spring, summer and fall periods. Navigational problems precluded sampling during the winter months. During March, April, and May the "complete" stations were visited twice monthly whenever possible. The time periods covered by this report are as follows:

1964: April through November
1965: April through November
1966: March through June

## METHODS

### SUSPENDED PARTICULATE MATTER

Water samples were obtained from Nansen bottle casts. Nine bottles were used in each cast except at shallow station A-6. One further exception is that during 1964 only eight bottles were used, the surface sample being obtained by plastic bucket. The top six bottles were set at 0, 5, 10, 15, 20, and 25 m from the surface. The three deepest bottles were positioned at 1/4, 1/2, and 3/4 of the distance between 25 m and the bottom. Equal aliquots (usually 50 ml) were obtained from the top six bottles and passed through a single preweighed membrane filter of 0.8μ pore size. Equal aliquots (usually 100 ml) were obtained from the three deepest bottles and similarly passed through a single preweighed membrane filter of 0.8μ pore size. At station A-6 sampling was limited to the surface and 5, 10, and

TABLE 1. Locations of Lake Michigan sampling stations.

| Station | Location | |
|---|---|---|
| | North latitude | West longitude |
| A-1 | 42°06'30" | 86°32'00" |
| A-2 | 42°06'00" | 86°37'00" |
| A-3 | 42°05'30" | 86°43'00" |
| A-4 | 42°03'30" | 87°06'30" |
| A-5 | 41°57'00" | 87°18'30" |
| A-6 | 41°52'00" | 87°27'00" |
| B-1 | 42°24'00" | 86°20'30" |
| B-2 | 42°24'00" | 86°27'00" |
| B-3 | 42°24'00" | 86°35'30" |
| B-4 | 42°23'30" | 87°01'30" |
| B-5 | 42°22'30" | 87°21'00" |
| B-6 | 42°22'30" | 87°30'00" |
| B-7 | 42°22'00" | 87°40'[illegible]0" |
| B-8 | 42°22'00" | 87°47'30" |
| C-1 | 42°49'40" | 86°14'50" |
| C-2 | 42°49'40" | 86°18'25" |
| C-3 | 42°49'10" | 86°28'25" |
| C-4 | 42°48'50" | 86°41'30" |
| C-5 | 42°49'00" | 86°50'00" |
| C-6 | 42°47'40" | 87°26'50" |
| C-7 | 42°47'30" | 87°34'30" |
| C'-1 | 43°08'00" | 86°23'00" |
| C'-2 | 43°12'00" | 86°31'00" |
| D-1 | 43°57'00" | 86°33'00" |
| D-2 | 43°56'00" | 86°39'30" |
| D-3 | 43°54'00" | 86°51'30" |
| D-4 | 43°48'00" | 87°05'00" |
| D-5 | 43°38'40" | 87°31'00" |
| D-6 | 43°44'00" | 87°38'00" |
| E-1 | 44°37'30" | 86°18'12" |
| E-2 | 44°37'00" | 86°21'42" |
| E-3 | 44°34'00" | 86°40'00" |
| E-4 | 44°30'18" | 86°55'18" |
| E-5 | 44°25'30" | 87°10'18" |
| E-6 | 44°27'40" | 87°26'25" |

15 m because of shallow water. Equal aliquots from these four depths were filtered through one preweighed filter. Gelman GM-4 filters were used until the middle of June 1964, and Millipore AA filters thereafter. This sampling procedure was carried out in triplicate each time a station was occupied.

Before preweighing the filters they were dried for at least 24 hours in a desiccator containing silica gel. Immediately after filtration the filters were returned to a desiccator. After at least 24 hours in a desiccator the filters with the samples were weighed. They were then heated in a muffle furnace at 600°C for 40 minutes, and, after cooling, the resulting ash was swept onto a small piece of preweighed aluminum foil which was then folded to prevent loss of ash. The foil plus ash were weighed. All weighings were made on a Cahn Gram Electrobalance. The dry weight of particulate matter on each filter was obtained by subtracting the weight of the preweighed filter from the weight of the filter after filtration and drying; likewise the weight of the ash was obtained by subtracting the weight of the preweighed foil from the weight of the foil and the ash. The weight of ash was then subtracted from the weight of particulate matter to obtain the dry ash-free weight of particulate matter.

Usually six control filters were included in the desiccators with the filters for the stations on each transect. These controls underwent the same procedures and conditions as the experimental filters except that distilled water was filtered instead of lake water. Any difference in weight of the controls before and after the sampling procedure was applied as a correction factor to the experimental filters with which they were processed.

Rarely copepods or other zooplankters were observed on the filters and picked off with forceps. The filters usually appeared to contain no large zooplankters.

## ZOOPLANKTON

Samples for the determination of the dry and ash-free weights of zooplankton were collected with a half-meter nylon plankton net, of #5 mesh size. The collections were made in triplicate at each station by towing the net vertically from within 5 m of the bottom to the surface. The samples were then hosed vigorously while still in the net and until most of the phytoplankton and other organisms that could be washed through the meshes of a #5 net had been removed. The washing was discontinued when the sample no longer appeared distinctly green or brownish green to the naked eye.

After washing, the zooplankton samples were filtered onto Whatman No. 40 "ashless" filter paper contained in porcelain crucibles, both of which had been dried at 40-60°C for 24 hours and preweighed. On the ships the filters were allowed to dry to prevent rotting. In the laboratory they were placed in the oven at 40-60°C to assure complete drying, after which the crucibles with their filters and samples were weighed. They were ashed at 600°C for 45 minutes and the weight of the crucibles and ash determined. The ash was then swept from the crucibles and the empty crucibles were weighed. The dry ash-free weight of the zooplankton was calculated by a subtraction procedure similar to that used for the suspended particulate matter, i.e., obtaining the dry and ash weights by subtracting the tare weight from the gross weight and then subtracting the ash weight from the dry weight. An Ainsworth Right-A-Weigh balance was used for the weighings.

Three control filters were included with filters for the three stations on each transect and were processed with the sample filters. Any difference in weights of controls between the gross and tare weights for both dry weight and ash weight were averaged and the average applied as a correction factor to the samples with which the controls were processed.

Specimens of the mysid, *Mysis relicta* Loven, were removed from any net samples in which they appeared before processing of the sample, since it was felt that they were not sampled representatively and their large size would strongly bias any samples in which they occurred.

## BENTHOS

Macrobenthos was sampled in triplicate at each station. A Smith-McIntyre dredge was used until June 1965, and a Ponar grab sampler thereafter. The entire sample from each dredge haul was washed into a large tub and subsequently transferred to the hopper of the combination elutriation-screening device described by Powers and Robertson (1965). The organisms, after separation from most of the sediment, were preserved in buffered formalin in mason jars.

In the laboratory the organisms in each sample were enumerated according to major taxonomic grouping. Amphipods, oligochaetes, sphaeriids, and tendipedids comprised practically all of each sample. Occasional additional organisms such as leeches, snails, roundworms, flatworms, mysids, ostracods, and bryozoan colonies were found. Ostracods, mysids, and roundworms, as well as bryozoans, were not considered to be sampled adequately and were eliminated from quantitative consideration by sorting them out. The remaining additional organisms were retained in the sample and were sorted and tabulated as a single group under the category "others."

After sorting and counting, each sample was recombined in a porcelain crucible, oven-dried 24 hours at 40-60°C, and the weight of crucible plus dry organisms obtained. The crucibles were then transferred to a muffle furnace and the samples ashed at 600°C for 45 minutes, after which the crucibles and contents were weighed. The ash was then carefully swept from the crucible, discarded, and the weight of the empty crucible obtained. Dry weight and dry ash-free weight of macrobenthos were thereby calculated.

Three control crucibles accompanied each 17 experimental crucibles and were subjected to the same procedures and conditions.

## FILTERABLE RESIDUE ON EVAPORATION

The water which passed through the membrane filters in the suspended particulate matter procedure was retained and frozen in 500-ml polyethylene bottles. In the laboratory the samples were thawed quickly by immersing in hot water, the sample shaken, and a 250-ml aliquot transferred to a preweighed 250-ml crucible. The sample was evaporated to dryness in a hot water bath, after which the crucible was removed from the bath, allowed to dry and cool, and weighed. Dry weight of filterable residue was obtained as the difference between the weight of crucible plus sample and the weight of the crucible alone.

Three empty control crucibles accompanied each set of 10 experimental crucibles.

## EXPLANATION OF DATA SHEETS

The biological data contained in this report were transferred to data cards in a format suitable for analysis and print-out on the IBM 7090 computer. The following tabulation of data is a computer print-out in which the stations are arranged serially by year, beginning with 1964. Hence, for each year the tabulation begins with station A-1 and finishes with station E-6. Beginning with the left-hand column, the following categories of information are reported:

Date

Dpth, metr = depth in meters

Sfc Tem C = surface temperature, °C

Benthic organisms per square meter = number of macrobenthic organisms per square mater of lake bottom

Amph = amphipods

Oligo = oligochaetes

Sphae = sphaeriids

Tend = tendipedids

Oth = other benthic organisms

Wt of benth organ mg/$m^2$ = weight of macrobenthic organisms per square meter of lake bottom

Dry = dry weight of macrobenthos

Ash free = ash-free weight (loss on ignition) of macrobenthos

Suspended particulate matter, mg/l

Dry = dry weight of suspended particulate matter

Ash-free = ash-free weight (loss on ignition) of suspended particulate matter

0-25 = combined sample from surface, 5, 10, 15, 20, 25 m

>25 = combined sample from 1/4, 1/2, and 3/4 the distance between 25 m and bottom

Filterable residue on evaporation, mg/l

0-25 = combined sample from surface, 5, 10, 15, 20, 25 m

>25 = combined sample from 1/4, 1/2, and 3/4 the distance between 25 m and bottom

Zooplk mg/$m^2$ = weight of zooplankton in a column of water one square meter in cross-sectional area extending from the surface to 5 m off bottom

Dry = dry weight of zooplankton

Ash free = ash-free weight (loss on ignition) of zooplankton

When the notations "--" or "-1" appear in the columns of tabulated data, it indicates that no data exist for that particular place in the table. Two dashes (--) are used when the parameter is one that was not included in the observation routine for that station. For example, at station A-1, which was not a "complete" station, suspended particulate matter, filterable residue on evaporation, and zooplankton were never sampled, and those columns appear simply as dashes. The notation "minus one" (-1) is used to indicate that the parameter in question is ordinarily measured at that station but for some reason was missed, or else the data were discarded. At station A-3, for example, the benthos columns from April through 1 August contain the notation "-1" because the Petersen dredge was used and the data were not considered valid.

## REFERENCES

AYERS, J. C., and J. L. HOUGH. 1964. Studies on water movements and sediments in southern Lake Michigan. Part II. The surficial bottom sediments in 1962-1963. Special Report No. 19, Great Lakes Research Division, Univ. of Michigan, Ann Arbor. 47 p.

EGGLETON, F. E. 1936. The deep-water bottom fauna of Lake Michigan. Papers Mich. Acad. Sci., 21: 599-612.

POWERS, C. F., and A. ROBERTSON. 1965. Some quantitative aspects of the macrobenthos of Lake Michigan. Proc. 8th Conf. on Great Lakes Research; Univ. of Michigan, Great Lakes Res. Div. Pub. 13: 153-159.

__________, and __________. 1967. Zonation of the benthic environment in Lake Michigan. In this report.

ROBERTSON, A., and W. P. ALLEY. 1966. A comparative study of Lake Michigan macrobenthos. Limnol. and Oceanogr., 11: 576-583.

__________, and C. F. POWERS. 1967. Comparison of the distribution of organic matter in the five Great Lakes. In this report.

STATION A-1 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L |  |  |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M³ |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 17 AUG | 16 | 15.1 | 355 | 81 | 33 | 98 | 0 | 103 | 96 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 375 | 147 | 33 | 130 | 0 | 139 | 117 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 326 | 65 | 33 | 0 | 0 | 96 | 86 | -- | -- | -- | -- | -- | -- | -- | -- |
| 20 SEPT | 16 | -1.0 | 1874 | 522 | 1760 | 196 | 0 | 16805 | 5769 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 4727 | 1030 | 1728 | 0 | 16 | 19607 | 4999 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 1891 | 1385 | 782 | 342 | 0 | 4701 | 1769 | -- | -- | -- | -- | -- | -- | -- | -- |
| 16 OCT | 16 | 15.0 | 33 | 49 | 81 | 0 | 0 | 86 | 46 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 717 | 16 | 16 | 33 | 0 | 365 | 313 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 81 | 49 | 0 | 0 | 0 | 78 | 52 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10 NOV | 19 | 12.5 | 1141 | 391 | 244 | 0 | 0 | 1573 | 558 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 2700 | 391 | 913 | 81 | 0 | 3465 | 2434 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 2059 | 619 | 1418 | 16 | 0 | 7151 | 3004 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION A-2 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L |  |  |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M³ |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 17 AUG | 30 | 20.3 | 4026 | 7490 | 7351 | 16 | 0 | 17115 | 10967 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 4670 | 3081 | 7253 | 81 | 33 | 14725 | 5961 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 4222 | 4545 | 8134 | 49 | 16 | 15558 | 5154 | -- | -- | -- | -- | -- | -- | -- | -- |
| 20 SEPT | 36 | -1.0 | 6716 | 3456 | 2347 | 0 | 0 | 13677 | 5866 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 7575 | 2983 | 1923 | 0 | 0 | 13284 | 10253 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 9193 | 5066 | 3423 | 0 | 0 | 16549 | 11304 | -- | -- | -- | -- | -- | -- | -- | -- |
| 16 OCT | 34 | 15.3 | 8427 | 4659 | 3004 | 16 | 0 | 14142 | 9599 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 10497 | 6514 | 5102 | 33 | 0 | 16972 | 10748 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 10481 | 5856 | 2737 | 16 | 0 | 15665 | 10093 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10 NOV | 36 | 12.5 | 11149 | 4401 | 4238 | 0 | 0 | 15961 | 11198 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 9307 | 5453 | 4205 | 0 | 0 | 14359 | 5669 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 8655 | 5575 | 3227 | 49 | 16 | 14944 | 5920 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION A-3 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L |  |  |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M³ |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 24 APR | 75 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.83 | 1.53 | 1.47 | 1.50 | -1 | -1 | 318 | 230 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.73 | 2.80 | 1.63 | 2.27 | -1 | -1 | 442 | 275 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.03 | 1.57 | 1.73 | 1.23 | -1 | -1 | -1 | -1 |
| 4 MAY | 84 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.50 | 2.77 | 1.23 | 1.87 | -1 | -1 | 844 | 441 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.63 | 1.80 | 1.30 | 1.33 | -1 | -1 | 504 | 434 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.93 | 2.63 | 1.63 | 1.40 | -1 | -1 | 162 | 126 |
| 20 MAY | 66 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.90 | 2.33 | 1.10 | -1.00 | -1 | -1 | 2018 | 334 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.67 | 2.20 | 1.20 | 1.73 | -1 | -1 | 349 | 220 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.57 | 1.83 | 1.17 | 1.47 | -1 | -1 | 601 | 501 |
| 6 JUNE | 75 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.77 | 1.33 | 1.00 | .83 | -1 | -1 | 451 | 287 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.60 | 1.10 | .80 | .87 | -1 | -1 | 289 | 167 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.77 | 1.30 | 1.70 | .57 | -1 | -1 | 1020 | 454 |
| 19 JUNE | 61 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 288 | 194 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 500 | 343 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 461 | 382 |
| 28 JUNE | 78 | -1.0 | -1 | -1 | -1 | -1 |  | -1 | -1 | 1.60 | 2.10 | .73 | .33 | -1 | -1 | 528 | 486 |
|  |  |  | -1 | -1 | -1 | -1 |  | -1 | -1 | -1.00 | 1.77 | -1.00 | .47 | -1 | -1 | 412 | 364 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | 1.70 | -1.00 | .87 | -1 | -1 | 662 | 556 |
| 22 JULY | 73 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 281 | 208 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 423 | 351 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 199 | 158 |
| 1 AUG | 54 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.37 | 4.03 | .70 | .73 | -1 | -1 | 163 | 148 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .33 | 3.30 | -1.00 | .20 | -1 | -1 | 302 | 270 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.50 | 3.07 | .90 | -1.00 | -1 | -1 | 354 | 314 |
| 18 AUG | 70 | 15.5 | 3716 | 733 | 1011 | 0 | 33 | 4768 | 4052 | 2.53 | 2.17 | .53 | .60 | -1 | -1 | 736 | 652 |
|  |  |  | 3374 | 1222 | 831 | 0 | 0 | 3566 | 2901 | 3.50 | 2.27 | 1.00 | .70 | -1 | -1 | 778 | 672 |
|  |  |  | 2555 | 1402 | 538 | 0 | 0 | 3518 | 2991 | 3.07 | 2.13 | .73 | .60 | -1 | -1 | 863 | 752 |
| 20 SEPT | 68 | 16.0 | 2478 | 1027 | 310 | 0 | 0 | 2835 | 2323 | 1.43 | 1.73 | .63 | .80 | -1 | -1 | 232 | 207 |
|  |  |  | 1793 | 733 | 179 | 0 | 0 | 2054 | 1769 | 1.57 | 1.60 | .83 | .60 | -1 | -1 | 242 | 199 |
|  |  |  | 3602 | 619 | 65 | 0 | 0 | 3324 | 2949 | 1.73 | 1.33 | .83 | .50 | -1 | -1 | 265 | 203 |
| 16 OCT | 71 | 15.3 | 3541 | 342 | 391 | 0 | 0 | 3143 | 2662 | 1.00 | 1.27 | .80 | .47 | -1 | -1 | 237 | 172 |
|  |  |  | 3195 | 766 | 359 | 0 | 0 | 3035 | 887 | .93 | 1.27 | .47 | .53 | -1 | -1 | 544 | 471 |
|  |  |  | 3945 | 766 | 535 | 0 | 0 | 3953 | 3250 | 1.03 | 1.17 | .53 | .60 | -1 | -1 | 623 | 531 |
| 10 NOV | 73 | 12.5 | 2592 | 1239 | 16 | 0 | 0 | 3033 | 2562 | 1.67 | 1.37 | 1.17 | .63 | -1 | -1 | 748 | 700 |
|  |  |  | 3046 | 1353 | 65 | 0 | 0 | 3669 | 3131 | 1.53 | 1.30 | 1.30 | .97 | -1 | -1 | 694 | 645 |
|  |  |  | 3139 | 1663 | 424 | 0 | 0 | 4544 | 3350 | 1.63 | 1.53 | .83 | .67 | -1 | -1 | 672 | 623 |

STATION A-4 1964

| | | | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | DRY | | ASH FREE | | | | | |
| DATE | DPTH METR | SFC TEM C | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 25 APR | 73 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.00 | -1.00 | 1.57 | -1.00 | -1 | -1 | 285 | 173 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.60 | 1.57 | 1.90 | 1.33 | -1 | -1 | 436 | 228 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.07 | .93 | 1.60 | .40 | -1 | -1 | -1 | -1 |
| 4 MAY | 75 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.40 | 2.37 | 1.03 | -1.00 | -1 | -1 | 248 | 204 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.53 | 2.13 | 1.17 | -1.00 | -1 | -1 | 521 | 445 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.57 | 2.07 | 1.43 | -1.00 | -1 | -1 | 363 | 222 |
| 20 MAY | 79 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.03 | 1.80 | .97 | 1.50 | -1 | -1 | 405 | 227 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.40 | 1.93 | .80 | 1.63 | -1 | -1 | 343 | 234 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.77 | 1.63 | 1.30 | 1.10 | -1 | -1 | 575 | 381 |
| 6 JUNE | 73 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .80 | 1.30 | .33 | 1.30 | -1 | -1 | 475 | 432 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.23 | 1.60 | .90 | 1.07 | -1 | -1 | 596 | 534 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.17 | 1.43 | .80 | 1.20 | -1 | -1 | 324 | 281 |
| 19 JUNE | 75 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 158 | 132 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 338 | 222 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 525 | 388 |
| 28 JUNE | 73 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .97 | 1.60 | .30 | .67 | -1 | -1 | 839 | 759 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.20 | 1.23 | .57 | .30 | -1 | -1 | 471 | 370 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | 1.10 | -1.00 | .73 | -1 | -1 | 591 | 472 |
| 22 JULY | 75 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 695 | 605 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 540 | 472 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 538 | 474 |
| 1 AUG | 72 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | 1.33 | -1.00 | .27 | -1 | -1 | 471 | 425 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.27 | 1.43 | .53 | .47 | -1 | -1 | 266 | 232 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .93 | 1.13 | .20 | .23 | -1 | -1 | 476 | 436 |
| 17 AUG | 72 | 20.5 | 1190 | 98 | 407 | 33 | 0 | 2300 | 1554 | 1.83 | 1.40 | .53 | .67 | -1 | -1 | 595 | 468 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.43 | 1.43 | .87 | .47 | -1 | -1 | 501 | 445 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.37 | 1.77 | .40 | .53 | -1 | -1 | 594 | 392 |
| 20 SEPT | 78 | 15.5 | 2918 | 636 | 147 | 0 | 0 | 2231 | 1967 | 1.60 | 1.43 | .37 | .70 | -1 | -1 | 389 | 203 |
| | | | 2119 | 391 | 212 | 0 | 0 | 1641 | 1451 | 2.27 | .87 | 1.33 | .47 | -1 | -1 | 473 | 399 |
| | | | 2852 | 701 | 179 | 0 | 0 | 2153 | 1860 | 1.67 | 1.07 | .43 | .70 | -1 | -1 | 305 | 222 |
| 17 OCT | 74 | 14.6 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.23 | 1.00 | .67 | .60 | -1 | -1 | 465 | 398 |
| | | | 2054 | 375 | 212 | 0 | 0 | 1459 | 1250 | 1.00 | .93 | .47 | .40 | -1 | -1 | 510 | 465 |
| | | | 1483 | 685 | 114 | 0 | 0 | 1474 | 1267 | 1.00 | .90 | .70 | .43 | -1 | -1 | 320 | 293 |
| 10 NOV | 77 | 12.3 | 2298 | 636 | 293 | 16 | 0 | 1276 | 1009 | 1.23 | .90 | .60 | .50 | -1 | -1 | 581 | 452 |
| | | | 1907 | 668 | 277 | 0 | 0 | 1540 | 1165 | 1.47 | 1.23 | 1.73 | .90 | -1 | -1 | 773 | 691 |
| | | | 407 | 636 | 3 | 16 | 0 | 574 | 383 | 1.03 | 1.10 | 1.60 | .47 | -1 | -1 | 930 | 857 |

STATION A-5 1964

| | | | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | DRY | | ASH FREE | | | | | |
| DATE | DPTH METR | SFC TEM C | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 20 SEPT | 43 | 18.8 | 636 | 81 | 81 | 0 | 0 | 540 | 473 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3912 | 717 | 750 | 0 | 0 | 2963 | 2408 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6813 | 1222 | 1565 | 0 | 0 | 6703 | 5544 | -- | -- | -- | -- | -- | -- | -- | -- |
| 17 OCT | 47 | 14.5 | 6438 | 1027 | 570 | 0 | 0 | 6394 | 5328 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5884 | 1304 | 1011 | 0 | 0 | 6685 | 5369 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6438 | 1760 | 1076 | 0 | 0 | 6934 | 5637 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10 NOV | 42 | 12.5 | 1092 | 81 | 179 | 0 | 0 | 1029 | 859 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 701 | 179 | 65 | 0 | 0 | 694 | 621 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2331 | 864 | 65 | 65 | 16 | 1816 | 1498 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION A-6 1964

| | | | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE | DPTH METR | SFC TEM C | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 25 APR | 17 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.95 | -1.00 | 1.90 | -1.00 | -1 | -1 | 204 | 183 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.68 | -1.00 | 1.33 | -1.00 | -1 | -1 | 176 | 114 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.45 | -1.00 | 2.35 | -1.00 | -1 | -1 | -1 | -1 |
| 4 MAY | 18 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.95 | -1.00 | 1.68 | -1.00 | -1 | -1 | 41 | 0 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.95 | -1.00 | -1.00 | -1.00 | -1 | -1 | 111 | 19 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 4.20 | -1.00 | 1.95 | -1.00 | -1 | -1 | 48 | 0 |
| 20 MAY | 20 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 5.90 | -1.00 | 1.73 | -1.00 | -1 | -1 | 469 | 250 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 4.50 | -1.00 | 1.10 | -1.00 | -1 | -1 | 153 | 71 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 5.17 | -1.00 | 1.43 | -1.00 | -1 | -1 | 360 | 139 |
| 6 JUNE | 20 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 20.00 | -1.00 | 3.00 | -1.00 | -1 | -1 | 65 | 30 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 18.05 | -1.00 | 2.35 | -1.00 | -1 | -1 | 98 | 36 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.05 | -1.00 | 1.60 | -1.00 | -1 | -1 | 102 | 35 |
| 19 JUNE | 15 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 87 | 38 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 99 | 39 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 84 | 38 |
| 28 JUNE | 18 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.55 | -1.00 | 1.45 | -1.00 | -1 | -1 | 20 | 9 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.45 | -1.00 | 1.20 | -1.00 | -1 | -1 | 19 | 12 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.10 | -1.00 | 1.10 | -1.00 | -1 | -1 | 23 | 10 |
| 22 JULY | 18 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 71 | 37 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 54 | 30 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 53 | 30 |
| 1 AUG | 18 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.90 | -1.00 | 1.55 | -1.00 | -1 | -1 | 141 | 111 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.25 | -1.00 | .85 | -1.00 | -1 | -1 | 101 | 71 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.95 | -1.00 | .75 | -1.00 | -1 | -1 | 32 | 16 |
| 18 AUG | 18 | 20.1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 182 | 118 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 4.93 | -1.00 | 1.60 | -1.00 | -1 | -1 | 193 | 108 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 6.80 | -1.00 | 1.27 | -1.00 | -1 | -1 | -1 | -1 |
| 20 SEPT | 17 | 16.5 | 1125 | 277 | 619 | 16 | 16 | 7557 | 870 | 1.33 | -1.00 | .43 | -1.00 | -1 | -1 | 54 | 22 |
| | | | 1500 | 16 | 49 | 0 | 0 | 1490 | 375 | 1.80 | -1.00 | .83 | -1.00 | -1 | -1 | 91 | 45 |
| | | | 1826 | 407 | 228 | 49 | 16 | 4756 | 839 | 1.60 | -1.00 | .60 | -1.00 | -1 | -1 | 108 | 58 |
| 17 OCT | 18 | 14.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.75 | -1.00 | .90 | -1.00 | -1 | -1 | 165 | 137 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.50 | -1.00 | .90 | -1.00 | -1 | -1 | 123 | 105 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.45 | -1.00 | .95 | -1.00 | -1 | -1 | 152 | 138 |
| 9 NOV | 15 | 12.5 | 16 | 49 | 0 | 0 | 33 | 168 | 72 | 2.03 | -1.00 | 1.10 | -1.00 | -1 | -1 | 124 | 69 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.83 | -1.00 | .83 | -1.00 | -1 | -1 | 271 | 209 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.83 | -1.00 | 1.10 | -1.00 | -1 | -1 | 272 | 237 |

STATION B-1 1964

| | | | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE | DPTH METR | SFC TEM C | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 17 AUG | 20 | 19.5 | 1304 | 1711 | 2298 | 0 | 16 | 8160 | 2536 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6324 | 2787 | 1874 | 0 | 0 | 8844 | 3679 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 14295 | 3176 | 1059 | 130 | 33 | 14122 | 6601 | -- | -- | -- | -- | -- | -- | -- | -- |
| 21 SEPT | 18 | 18.0 | 4939 | 8199 | 2233 | 16 | 0 | 24620 | 7330 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6455 | 7645 | 1467 | 0 | 49 | 22840 | 7136 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7579 | 8150 | 1320 | 49 | 0 | 16663 | 5237 | -- | -- | -- | -- | -- | -- | -- | -- |
| 16 OCT | 14 | 13.7 | 130 | -1 | 0 | 0 | 0 | 36 | 31 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 65 | -1 | 0 | 33 | 0 | 28 | 23 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 424 | -1 | 0 | 33 | 0 | 158 | 127 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION B-2 1964

| | | | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE | DPTH METR | SFC TEM C | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 17 AUG | 47 | 20.0 | 7416 | -1 | 4515 | 65 | 0 | 8712 | 6722 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4988 | 1369 | 1418 | 33 | 0 | 7203 | 5581 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4238 | 1695 | 1271 | 65 | 0 | 5607 | 4438 | -- | -- | -- | -- | -- | -- | -- | -- |
| 21 SEPT | 47 | 18.7 | 4955 | 1728 | 1891 | 0 | 0 | 8300 | 6020 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8460 | 2836 | 4825 | 0 | 0 | 11563 | 8440 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6390 | 1630 | 2934 | 49 | 0 | 9073 | 6515 | -- | -- | -- | -- | -- | -- | -- | -- |
| 16 OCT | 46 | 14.0 | 6716 | 962 | 587 | 16 | 0 | 7231 | 5896 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6927 | 1288 | 1076 | 16 | 0 | 7734 | 6202 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7368 | 2168 | 2738 | 0 | 0 | 9744 | 7262 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION E-3 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 APR | 75 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.03 | 1.77 | 1.73 | 1.57 | -1 | -1 | 218 | 157 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.17 | 1.23 | -1.00 | .97 | -1 | -1 | 477 | 419 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.97 | 1.13 | 1.50 | .73 | -1 | -1 | -1 | -1 |
| 5 MAY | 70 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.80 | 3.93 | 1.25 | 2.00 | -1 | -1 | 562 | 337 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 4.00 | 3.47 | 1.73 | -1.00 | -1 | -1 | 1323 | 845 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.77 | 2.40 | 1.33 | 1.30 | -1 | -1 | 1433 | 780 |
| 18 MAY | 83 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.97 | 1.60 | 1.97 | 1.60 | -1 | -1 | 1194 | 906 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.33 | 1.70 | 1.33 | .90 | -1 | -1 | -1 | -1 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.53 | 1.80 | 1.20 | 1.57 | -1 | -1 | 712 | 544 |
| 5 JUNE | 64 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.63 | 2.37 | 1.20 | .60 | -1 | -1 | 220 | 104 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.13 | 2.17 | 1.10 | 1.57 | -1 | -1 | 560 | 298 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.73 | 3.60 | 1.00 | .80 | -1 | -1 | 917 | 342 |
| 18 JUNE | 64 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 231 | 179 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 256 | 202 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 241 | 179 |
| 29 JUNE | 64 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.67 | 2.77 | .87 | .27 | -1 | -1 | 970 | 862 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.87 | 3.37 | 1.10 | 1.77 | -1 | -1 | 1163 | 1020 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.80 | 4.00 | 1.03 | .93 | -1 | -1 | 558 | 472 |
| 14 JULY | 62 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.13 | 3.87 | .43 | .47 | -1 | -1 | 3339 | 2665 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.43 | 3.17 | .93 | .27 | -1 | -1 | 2999 | 2663 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.40 | 3.87 | 1.27 | .77 | -1 | -1 | 2256 | 2072 |
| 24 JULY | 62 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.13 | 3.43 | .93 | .77 | -1 | -1 | 344 | 293 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.33 | 3.30 | .73 | .67 | -1 | -1 | 502 | 445 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.13 | 3.30 | .67 | .93 | -1 | -1 | 705 | 644 |
| 2 AUG | 61 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.77 | 3.81 | 1.10 | 1.56 | -1 | -1 | 280 | 258 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.57 | 4.20 | 1.07 | 1.27 | -1 | -1 | 412 | 362 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.17 | 4.07 | .43 | 1.53 | -1 | -1 | 320 | 247 |
| 17 AUG | 65 | 20.1 | 2363 | -1 | 538 | 33 | 0 | 2662 | 2251 | 3.30 | 3.33 | .93 | .83 | -1 | -1 | 484 | 438 |
| | | | 3700 | -1 | 578 | 16 | 0 | 4249 | 3506 | 3.23 | 3.33 | .90 | .57 | -1 | -1 | 473 | 431 |
| | | | 2916 | 1206 | 608 | 6 | 0 | 4284 | 3474 | 2.93 | 3.30 | .63 | .67 | -1 | -1 | 453 | 416 |
| 21 SEPT | 64 | 20.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.77 | 2.20 | .77 | .93 | -1 | -1 | 651 | 580 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.37 | 2.77 | .37 | .50 | -1 | -1 | 809 | 693 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.53 | 1.93 | .60 | 1.17 | -1 | -1 | 1006 | 744 |
| 15 OCT | 67 | 15.1 | 1646 | 668 | 538 | 0 | 0 | 1910 | 1545 | 1.63 | 2.03 | .40 | 1.33 | -1 | -1 | 805 | 728 |
| | | | 2755 | 1027 | 570 | 0 | 0 | 3035 | 2491 | 1.80 | 1.83 | 1.00 | .87 | -1 | -1 | 511 | 462 |
| | | | 3553 | 1557 | 554 | 0 | 0 | 4103 | 3460 | 1.63 | 1.67 | .90 | .90 | -1 | -1 | 490 | 447 |

STATICN B-4 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGU | SPHAE | TENC | OTH | DRY | ASH FREE | DRY | | ASH FREE | | 0-25 | >25 | DRY | ASH FREE |
| | | | | | | | | | | 0-25 | >25 | 0-25 | >25 | | | | |
| 23 APR | 132 | -1.C | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.63 | 1.25 | 1.50 | .95 | -1 | -1 | 476 | 401 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.70 | 1.83 | 1.33 | 1.70 | -1 | -1 | 654 | 565 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.17 | .97 | -1.00 | .97 | -1 | -1 | -1 | -1 |
| 5 MAY | 137 | -1.C | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.30 | 1.03 | 1.17 | .87 | -1 | -1 | 560 | 495 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.70 | 1.23 | 1.57 | 1.17 | -1 | -1 | 399 | 342 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.90 | 1.23 | 1.47 | 1.10 | -1 | -1 | 366 | 322 |
| 18 MAY | 141 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.37 | 1.50 | 1.27 | 1.43 | -1 | -1 | 1209 | 805 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.57 | 1.23 | 1.43 | 1.20 | -1 | -1 | 716 | 510 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.40 | 1.67 | 1.27 | 1.40 | -1 | -1 | 1497 | 1174 |
| 5 JUNE | 147 | -1.C | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.20 | 1.17 | 1.03 | 1.17 | -1 | -1 | 756 | 603 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.07 | 1.20 | 1.00 | 1.10 | -1 | -1 | 488 | 287 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.20 | 1.07 | .90 | .93 | -1 | -1 | 336 | 229 |
| 17 JUNE | 139 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.0C | -1 | -1 | 635 | 547 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 367 | 306 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 395 | 344 |
| 29 JUNE | 120 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.40 | 1.17 | .53 | .63 | -1 | -1 | 1513 | 1415 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.47 | 1.07 | .70 | .87 | -1 | -1 | 1053 | 992 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .77 | .80 | .20 | .37 | -1 | -1 | 2013 | 1859 |
| 14 JULY | 135 | -1.C | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.47 | 1.23 | .70 | .43 | -1 | -1 | 2360 | 2107 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.50 | 1.00 | .87 | .57 | -1 | -1 | 3203 | 2925 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .80 | 1.07 | .27 | .37 | -1 | -1 | 2725 | 2463 |
| 24 JULY | 135 | -1.C | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.03 | 1.30 | .57 | .30 | -1 | -1 | 1272 | 1173 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.33 | 1.43 | .73 | .50 | -1 | -1 | 682 | 638 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.10 | 1.77 | .70 | .57 | -1 | -1 | 1698 | 1576 |
| 2 AUG | 123 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.43 | 1.67 | .97 | 1.47 | -1 | -1 | 1517 | 1427 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.47 | 1.40 | 1.00 | .87 | -1 | -1 | 1775 | 1678 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.13 | .80 | .90 | .40 | -1 | -1 | 1242 | 1167 |
| 16 AUG | 128 | 20.5 | 1011 | 554 | 114 | 16 | 0 | 1359 | 1195 | 2.53 | 1.33 | .70 | .47 | -1 | -1 | 787 | 648 |
| | | | 2119 | 619 | 81 | 16 | 0 | 2266 | 334 | 2.77 | 1.50 | .77 | .73 | -1 | -1 | 818 | 754 |
| | | | 1972 | 359 | 0 | 0 | 0 | 2293 | 2051 | 2.73 | 1.33 | .73 | .53 | -1 | -1 | 975 | 916 |
| 21 SEPT | 126 | 20.C | 2168 | 1353 | 0 | 0 | 0 | 2712 | 2290 | 1.93 | 1.23 | .57 | .63 | -1 | -1 | 948 | 844 |
| | | | 2135 | 228 | 16 | 0 | 0 | 1749 | 1593 | 1.60 | 1.30 | .53 | .77 | -1 | -1 | 992 | 893 |
| | | | 1956 | 570 | 0 | 0 | 0 | 1876 | 1700 | 1.57 | 1.43 | .60 | 1.03 | -1 | -1 | 1009 | 909 |
| 15 OCT | 128 | 15.0 | 848 | -1 | 16 | 0 | 0 | 910 | 810 | .93 | 1.10 | .53 | .70 | -1 | -1 | 674 | 628 |
| | | | 1027 | -1 | 33 | 0 | 0 | 1069 | 934 | 1.23 | 1.10 | 1.03 | .53 | -1 | -1 | 565 | 514 |
| | | | 1C92 | -1 | 0 | 0 | 0 | 720 | 606 | 1.13 | 1.00 | .53 | .57 | -1 | -1 | 470 | 434 |

STATICN B-5 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGU | SPHAE | TEND | OTH | DRY | ASH FREE | DRY | | ASH FREE | | 0-25 | >25 | DRY | ASH FREE |
| | | | | | | | | | | 0-25 | >25 | 0-25 | >25 | | | | |
| 16 AUG | 112 | 20.4 | 1565 | 212 | 81 | 81 | 0 | 1721 | 1541 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1059 | 456 | 114 | 0 | 0 | 1945 | 1736 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1530 | 440 | 16 | 0 | 0 | 2132 | 1948 | -- | -- | -- | -- | -- | -- | -- | -- |
| 15 OCT | 104 | 13.5 | 1923 | 179 | 0 | 16 | 0 | 2275 | 2077 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 310 | 147 | 0 | 0 | 0 | 409 | 352 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1691 | 603 | 293 | 0 | 0 | 2362 | 2142 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION B-6 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 23 APR | 88 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.80 | -1.00 | 2.23 | -1.00 | -1 | -1 | 421 | 338 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.77 | 2.93 | .77 | 1.93 | -1 | -1 | 412 | 330 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.07 | 2.20 | 1.60 | 1.97 | -1 | -1 | -1 | -1 |
| 5 MAY | 99 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.48 | 1.47 | .85 | .58 | -1 | -1 | 690 | 481 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.30 | 2.18 | .73 | .83 | -1 | -1 | 492 | 312 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.95 | 1.72 | .77 | .80 | -1 | -1 | 538 | 451 |
| 18 MAY | 86 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.25 | 2.90 | .88 | 2.17 | -1 | -1 | 887 | 764 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.03 | 1.87 | -1.00 | 1.20 | -1 | -1 | 805 | 724 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.63 | 2.43 | 1.47 | 1.33 | -1 | -1 | 827 | 752 |
| 5 JUNE | 86 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.90 | 1.40 | 1.23 | 1.20 | -1 | -1 | 529 | 437 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.17 | 1.17 | .97 | 1.10 | -1 | -1 | 645 | 585 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | 1.30 | -1.00 | 1.03 | -1 | -1 | 391 | 346 |
| 17 JUNE | 88 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 923 | 699 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 641 | 566 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 346 | 300 |
| 29 JUNE | 86 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.77 | 1.07 | .90 | .57 | -1 | -1 | 883 | 766 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.93 | 1.30 | 1.03 | .77 | -1 | -1 | 939 | 846 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.77 | 1.37 | .83 | .63 | -1 | -1 | 1381 | 832 |
| 11 JULY | 86 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.50 | 5.60 | .97 | 1.30 | -1 | -1 | 1062 | 819 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.67 | 2.80 | 1.20 | 1.10 | -1 | -1 | 1474 | 1234 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.33 | 2.80 | .57 | 1.00 | -1 | -1 | 1300 | 1144 |
| 24 JULY | 88 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.37 | 1.60 | .70 | .67 | -1 | -1 | 1052 | 966 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.37 | 1.47 | .77 | .63 | -1 | -1 | 542 | 503 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.33 | 1.50 | .70 | .47 | -1 | -1 | 566 | 527 |
| 2 AUG | 86 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .87 | 1.13 | [illegible] | .33 | -1 | -1 | 1549 | 1452 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .63 | 1.67 | .10 | 1.00 | -1 | -1 | 938 | 855 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.07 | .87 | .67 | .20 | -1 | -1 | 1038 | 935 |
| 16 AUG | 86 | 20.0 | 1711 | 391 | 196 | 81 | 0 | 1826 | 1633 | 2.27 | 1.30 | 1.03 | .43 | -1 | -1 | 522 | 446 |
| | | | 1581 | 147 | 114 | 16 | 0 | 1565 | 1374 | 1.90 | 1.13 | .70 | .60 | -1 | -1 | 313 | 278 |
| | | | 1157 | 16 | 98 | 0 | 0 | 1280 | 1144 | 1.77 | 1.13 | .73 | .43 | -1 | -1 | 405 | 360 |
| 19 SEPT | 83 | 19.2 | 2037 | 212 | 65 | 0 | 0 | 2262 | 2020 | 1.80 | 1.33 | .77 | .43 | -1 | -1 | 444 | 394 |
| | | | 3341 | 619 | 293 | 16 | 0 | 3355 | 2962 | 1.90 | 1.23 | .83 | .57 | -1 | -1 | 868 | 169 |
| | | | 2200 | 98 | 98 | 0 | 0 | 2007 | 1790 | 1.67 | 1.30 | .60 | .60 | -1 | -1 | 272 | 165 |
| 14 OCT | 79 | 13.5 | 1532 | 212 | 0 | 16 | 0 | 1739 | 1620 | 1.10 | 1.20 | .73 | .77 | -1 | -1 | 182 | 149 |
| | | | 1972 | 277 | 0 | 0 | 0 | 1742 | 1625 | 1.27 | 1.03 | .63 | .37 | -1 | -1 | 367 | 323 |
| | | | 929 | 489 | 147 | 0 | 0 | 1385 | 1265 | 1.30 | 1.93 | .83 | .80 | -1 | -1 | 407 | 345 |
| 8 NOV | 84 | 11.5 | 1092 | 750 | 65 | 16 | 0 | 1506 | 1284 | 1.47 | 1.80 | .83 | .87 | -1 | -1 | 1001 | 917 |
| | | | 1190 | 619 | 163 | 0 | 0 | 1751 | 1384 | 1.47 | 1.80 | .73 | .93 | -1 | -1 | 919 | 846 |
| | | | 1157 | 391 | 33 | 16 | 0 | 1421 | 1236 | 1.07 | 1.77 | .50 | .90 | -1 | -1 | 1046 | 913 |

STATION B-7 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 16 AUG | 45 | 15.0 | 5249 | 1052 | 1826 | 65 | 0 | 5258 | 4236 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4690 | 1320 | 2135 | 49 | 0 | 5446 | 4293 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4610 | 701 | 2412 | 16 | 0 | 4486 | 3508 | -- | -- | -- | -- | -- | -- | -- | -- |
| 19 SEPT | 43 | 16.5 | 5183 | 2347 | 2526 | 0 | 0 | 6435 | 4748 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4434 | 1923 | 1434 | 0 | 0 | 5842 | 4453 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6504 | 2126 | 1956 | 33 | 0 | 6145 | 4843 | -- | -- | -- | -- | -- | -- | -- | -- |
| 15 OCT | 44 | 8.5 | 4613 | 1753 | 1679 | 0 | 16 | 6075 | 4438 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5803 | 1532 | 1549 | 0 | 0 | 6341 | 4720 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4305 | 554 | 1255 | 0 | 0 | 4443 | 3946 | -- | -- | -- | -- | -- | -- | -- | -- |
| 8 NOV | 45 | 10.5 | 6046 | 2250 | 2200 | 49 | 16 | 8637 | 6184 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4776 | 2258 | 1614 | 163 | 0 | 7726 | 5705 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4319 | 1505 | 1614 | 0 | 16 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION B-8 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 AUG | 11 | -1.0 | 3814 | -1 | 1003 | 147 | 163 | 23272 | 4908 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6813 | -1 | 896 | 33 | 212 | 15126 | 4652 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5620 | -1 | 2298 | 49 | 163 | 26613 | 5281 | -- | -- | -- | -- | -- | -- | -- | -- |
| 15 SEPT | 16 | 17.0 | 4319 | 7824 | 1011 | 16 | 147 | 21527 | 6248 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4690 | 12812 | 6471 | 0 | 375 | 39334 | 9012 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3928 | 6357 | 2885 | 33 | 326 | 22036 | 5835 | -- | -- | -- | -- | -- | -- | -- | -- |
| 15 OCT | 11 | 5.8 | 6422 | 1728 | 1014 | 33 | 0 | 26269 | 8973 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7643 | 2054 | 2347 | 98 | 0 | 21004 | 8508 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5336 | 2494 | 2119 | 33 | 0 | 17884 | 7775 | -- | -- | -- | -- | -- | -- | -- | -- |
| 8 NOV | 11 | 5.0 | 49 | 147 | 130 | 0 | 33 | 947 | 367 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1402 | 1239 | 2298 | 49 | 1092 | 18481 | 5622 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 375 | 1597 | 1043 | 98 | 147 | 13584 | 4152 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C-1 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 AUG | 17 | -1.0 | 6052 | -1 | 619 | 424 | 0 | 5790 | 4650 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5575 | -1 | 147 | 130 | 0 | 5045 | 4111 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9503 | 228 | 473 | 326 | 33 | 11384 | 7351 | -- | -- | -- | -- | -- | -- | -- | -- |
| 17 SEPT | 20 | 17.2 | 9350 | 4450 | 1467 | 16 | 0 | 15972 | 8300 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6166 | 619 | 717 | 33 | 98 | 7604 | 5413 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9487 | 6716 | 2412 | 33 | 0 | 14127 | 8435 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 OCT | 20 | 13.5 | 2836 | 65 | 179 | 0 | 0 | 1827 | 1493 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1809 | 65 | 196 | 0 | 0 | 2170 | 1762 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1777 | 147 | 440 | 0 | 0 | 3219 | 2321 | -- | -- | -- | -- | -- | -- | -- | -- |
| 6 NOV | 24 | 16.0 | 11231 | 5509 | 4042 | 130 | 16 | 10553 | 8044 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9601 | 4336 | 2478 | 98 | 16 | 12310 | 7716 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2543 | 750 | 163 | 0 | 0 | 2598 | 2000 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C-2 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 AUG | 47 | -1.0 | 9694 | -1 | 310 | 65 | 0 | 9180 | 7954 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9014 | -1 | 2510 | 33 | 0 | 9265 | 7454 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7590 | 5102 | 4026 | 81 | 0 | 11047 | 8067 | -- | -- | -- | -- | -- | -- | -- | -- |
| 17 SEPT | 49 | 17.5 | 8867 | 9552 | 4042 | 16 | 0 | 13376 | 9082 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6178 | 1418 | 1760 | 0 | 0 | 7456 | 5700 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6683 | 1728 | 1581 | 0 | 0 | 8029 | 6121 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 OCT | 52 | 13.7 | 4482 | 2516 | 228 | 16 | 0 | 5413 | 4243 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9519 | 10562 | 1059 | 0 | 0 | 11844 | 8067 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4368 | 1581 | 489 | 0 | 0 | 4670 | 3314 | -- | -- | -- | -- | -- | -- | -- | -- |
| 6 NOV | 52 | 12.5 | 4662 | 10122 | 1451 | 0 | 0 | 7420 | 5374 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4091 | 12062 | 2119 | 0 | 0 | 7619 | 5532 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3178 | 3961 | 683 | 16 | 0 | 5330 | 4077 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C-3 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M$^2$ DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M$^2$ DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 APR | 86 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 347 | 139 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.30 | 3.93 | 2.50 | 3.60 | -1 | -1 | -1 | -1 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.70 | 3.70 | 1.63 | 3.40 | -1 | -1 | -1 | -1 |
| 15 MAY | 79 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.90 | 2.83 | 1.17 | 1.33 | -1 | -1 | 2387 | 1502 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.87 | 1.97 | 1.83 | 1.93 | -1 | -1 | 1226 | 880 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.23 | 2.03 | 1.50 | 1.87 | -1 | -1 | 862 | 689 |
| 16 JUNE | 84 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | 2.30 | -1.00 | .60 | -1 | -1 | 352 | 332 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | 2.80 | -1.00 | .70 | -1 | -1 | 669 | 610 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.93 | 2.90 | .97 | 1.30 | -1 | -1 | 703 | 607 |
| 8 JULY | 81 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.47 | 2.30 | .40 | .63 | -1 | -1 | 1149 | 1038 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.27 | 1.70 | .60 | .23 | -1 | -1 | 928 | 831 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.43 | 2.63 | .70 | .80 | -1 | -1 | 998 | 860 |
| 20 AUG | 77 | 16.9 | 3488 | 799 | 538 | 0 | 0 | 3399 | 2779 | 2.03 | 2.37 | .77 | .50 | -1 | -1 | 126 | 110 |
| | | | 3765 | 668 | 489 | 49 | 0 | 4015 | 3392 | 2.40 | 2.47 | 1.13 | .83 | -1 | -1 | 303 | 275 |
| | | | 4303 | 799 | 685 | 65 | 0 | 4181 | 3622 | 2.10 | 1.93 | .70 | .70 | -1 | -1 | 259 | 238 |
| 17 SEPT | 77 | 19.2 | 2885 | 1076 | 326 | 0 | 0 | 5301 | 3107 | 2.43 | 4.20 | .97 | 1.13 | -1 | -1 | 673 | 553 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.57 | 4.00 | 1.23 | 1.03 | -1 | -1 | 886 | 539 |
| | | | 2412 | 880 | 0 | 0 | 0 | 3426 | 2931 | 3.30 | 3.20 | 1.03 | 1.30 | -1 | -1 | 732 | 408 |
| 13 OCT | 79 | 14.0 | 2722 | 994 | 554 | 0 | 0 | 2698 | 2205 | 1.07 | 1.13 | .60 | .33 | -1 | -1 | 375 | 329 |
| | | | 2901 | 913 | 538 | 0 | 0 | 3082 | 2564 | 1.83 | 1.33 | .67 | .53 | -1 | -1 | 369 | 336 |
| | | | 2901 | 1320 | 212 | 0 | 0 | 3723 | 3201 | 1.13 | 1.67 | .47 | .50 | -1 | -1 | 337 | 310 |
| 6 NOV | 77 | 12.5 | 2396 | 310 | 407 | 0 | 0 | 2170 | 1835 | 1.33 | 1.43 | .73 | 1.17 | -1 | -1 | 569 | 537 |
| | | | 3195 | 489 | 538 | 0 | 0 | 2980 | 2445 | 1.17 | 1.43 | .83 | .67 | -1 | -1 | 742 | 703 |
| | | | 4857 | 538 | 375 | 0 | 0 | 3705 | 3185 | 1.40 | 1.43 | .90 | 1.10 | -1 | -1 | 552 | 515 |

STATION C-4 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M$^2$ DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M$^2$ DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 AUG | 111 | -1.0 | 2041 | 244 | 228 | 65 | 0 | 2386 | 2073 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3260 | 717 | 342 | 16 | 0 | 3177 | 2719 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3260 | 489 | 130 | 65 | 0 | 3336 | 2730 | -- | -- | -- | -- | -- | -- | -- | -- |
| 18 SEPT | 110 | 18.2 | 1206 | 114 | 49 | 0 | 0 | 1529 | 1384 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1646 | 196 | 179 | 0 | 0 | 1923 | 1700 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1711 | 293 | 342 | 16 | 0 | 1958 | 1623 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 OCT | 104 | 14.0 | 1711 | 660 | 277 | 0 | 0 | 1936 | 1575 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1728 | 636 | 293 | 0 | 0 | 1834 | 1490 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2738 | 473 | 114 | 0 | 0 | 2779 | 2487 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C-5 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M$^2$ DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M$^2$ DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 APR | 165 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.37 | 2.05 | 1.20 | 2.05 | -1 | -1 | 476 | 416 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.30 | -1.00 | 1.20 | -1.00 | -1 | -1 | -1 | -1 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.50 | 1.60 | 1.27 | 1.60 | -1 | -1 | -1 | -1 |
| 15 MAY | 120 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.30 | 1.53 | 1.10 | 1.47 | -1 | -1 | 462 | 352 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.57 | 1.40 | 1.50 | 1.33 | -1 | -1 | 436 | 356 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.00 | 2.00 | .97 | 1.80 | -1 | -1 | 1056 | 886 |
| 16 JUNE | 167 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | .80 | -1.00 | -1.00 | -1 | -1 | 1061 | 966 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.27 | .80 | .87 | .77 | -1 | -1 | 391 | 338 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.27 | .67 | .70 | .67 | -1 | -1 | 668 | 638 |
| 10 JULY | 165 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.27 | .73 | .83 | .30 | -1 | -1 | 2314 | 2096 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .83 | -1.00 | .20 | -1.00 | -1 | -1 | 1528 | 1440 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .77 | .57 | -1.00 | .50 | -1 | -1 | 2431 | 2173 |
| 20 AUG | 153 | 16.7 | 2820 | 1222 | 33 | 33 | 0 | 2421 | 2137 | 1.93 | .73 | .73 | .63 | -1 | -1 | 1683 | 1585 |
| | | | 2412 | 1043 | 0 | 196 | 0 | 2365 | 2013 | 1.57 | .67 | .73 | .40 | -1 | -1 | 684 | 629 |
| | | | 1842 | 701 | 33 | 16 | 0 | 1711 | 1449 | 1.73 | .50 | .57 | .50 | -1 | -1 | 2266 | 2161 |
| 22 SEPT | 157 | 16.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.83 | 2.07 | 1.03 | .93 | -1 | -1 | 843 | 710 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.87 | 1.50 | .60 | .43 | -1 | -1 | 636 | 551 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.67 | 2.53 | 1.00 | .90 | -1 | -1 | 885 | 794 |
| 13 OCT | 156 | 13.5 | 680 | -1 | 33 | 0 | 0 | 654 | 574 | 1.17 | .97 | .40 | .40 | -1 | -1 | 583 | 538 |
| | | | 750 | -1 | 33 | 0 | 0 | 572 | 500 | 1.50 | .77 | .70 | .33 | -1 | -1 | 604 | 551 |
| | | | 978 | -1 | 49 | 0 | 0 | 703 | -1 | 1.07 | 1.23 | .50 | .67 | -1 | -1 | 584 | 541 |

STATION C-6 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L |  |  |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M² |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 20 AUG | 98 | -1.0 | 2836 | 619 | 65 | 33 | 0 | 3650 | 3249 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 2070 | 326 | 49 | 16 | 0 | 2559 | 2333 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 2347 | 522 | 196 | 65 | 0 | 2650 | 2352 | -- | -- | -- | -- | -- | -- | -- | -- |
| 22 SEPT | 99 | -1.0 | 2543 | 81 | 114 | 33 | 0 | 2546 | 2233 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 3113 | 473 | 163 | 0 | 0 | 2967 | 2629 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 2445 | 1418 | 196 | 0 | 0 | 3465 | 2945 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 OCT | 98 | 12.2 | 2184 | 391 | 196 | 0 | 0 | 2613 | 2419 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 1744 | 326 | 326 | 0 | 0 | 2049 | 1827 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 2119 | 733 | 147 | 16 | 0 | 2352 | 2122 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C-7 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L |  |  |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M² |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 16 MAY | 55 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.17 | 2.33 | 1.77 | 2.07 | -1 | -1 | 200 | 170 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.17 | 2.43 | 2.07 | 1.43 | -1 | -1 | -1 | -1 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.50 | 2.40 | -1.00 | 1.27 | -1 | -1 | 67 | 56 |
| 16 JUNE | 55 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.73 | 2.10 | .97 | 1.43 | -1 | -1 | 428 | 380 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.03 | 2.10 | .83 | .83 | -1 | -1 | 332 | 298 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.60 | 2.23 | .97 | .73 | -1 | -1 | 451 | 389 |
| 10 JULY | 59 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.43 | 2.80 | 1.03 | .80 | -1 | -1 | 671 | 561 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.93 | 2.70 | 1.67 | .90 | -1 | -1 | 405 | 328 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.37 | 2.47 | 1.00 | .60 | -1 | -1 | 476 | 382 |
| 20 AUG | 55 | 20.0 | 3993 | 717 | 456 | 16 | 0 | 3813 | 3366 | 1.83 | 1.50 | .83 | .60 | -1 | -1 | 389 | 344 |
|  |  |  | 5884 | 1222 | 864 | 0 | 0 | 5270 | 4505 | 1.80 | 1.57 | .90 | .40 | -1 | -1 | 766 | 705 |
|  |  |  | 6553 | 733 | 815 | 65 | 0 | 5123 | 4567 | 1.93 | 1.23 | 1.07 | .47 | -1 | -1 | 458 | 406 |
| 22 SEPT | 65 | 17.1 | 3521 | 668 | 538 | 0 | 0 | 4068 | 3443 | 2.33 | 2.53 | 1.17 | .67 | -1 | -1 | 267 | 240 |
|  |  |  | 1516 | 636 | 81 | 0 | 0 | 2227 | 2003 | 2.17 | 2.10 | .97 | .63 | -1 | -1 | 285 | 263 |
|  |  |  | 4434 | 945 | 391 | 0 | 0 | 4722 | 4326 | 2.77 | 2.03 | 1.13 | .63 | -1 | -1 | 238 | 207 |
| 14 OCT | 70 | 10.6 | 3977 | -1 | 130 | 0 | 0 | 3345 | 3009 | 1.40 | 1.53 | .67 | .83 | -1 | -1 | 238 | 205 |
|  |  |  | 4580 | -1 | 228 | 0 | 0 | 3783 | 3402 | 1.27 | 1.20 | .60 | .53 | -1 | -1 | 481 | 377 |
|  |  |  | 5167 | -1 | 212 | 0 | 0 | 4220 | 3772 | 1.53 | 1.63 | .67 | .80 | -1 | -1 | 244 | 205 |
| 6 NOV | 54 | 9.0 | 4417 | 1467 | 685 | 16 | 0 | 4745 | 3964 | 1.63 | 1.63 | 1.03 | .63 | -1 | -1 | 923 | 475 |
|  |  |  | 3667 | 1125 | 913 | 16 | 0 | 3803 | 2999 | 2.03 | 1.53 | 1.17 | .87 | -1 | -1 | 845 | 663 |
|  |  |  | 4466 | 1052 | 636 | 33 | 0 | 4844 | 4018 | 1.37 | 1.43 | .67 | .63 | -1 | -1 | 338 | 273 |

STATION C*-1 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L |  |  |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M² |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 10 SEPT | 36 | 15.3 | 8329 | 147 | 668 | 33 | 0 | 6024 | 5240 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 9527 | 212 | 750 | 49 | 0 | 8344 | 7348 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 11214 | 766 | 293 | 0 | 0 | 8667 | 7747 | -- | -- | -- | -- | -- | -- | -- | -- |
| 16 OCT | 38 | 14.3 | 13676 | 570 | 1874 | 0 | 0 | 7405 | 5834 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 13187 | 1851 | 3293 | 81 | 0 | 10187 | 7883 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 11426 | 1809 | 3325 | 33 | 0 | 8531 | 6483 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10 NOV | 39 | 11.7 | 14018 | 2836 | 831 | 179 | 0 | 9531 | 7029 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 9177 | 2266 | 831 | 49 | 0 | 7881 | 6289 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 10530 | 3374 | 1744 | 228 | 0 | 8978 | 7016 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C*-2 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L |  |  |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M² |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 10 AUG | 87 | 17.5 | 5526 | 1206 | 391 | 49 | 0 | 4471 | 4055 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 5477 | 1157 | 799 | 16 | 0 | 5172 | 4556 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10 SEPT | 89 | 15.5 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 5395 | 505 | 375 | 33 | 0 | 5379 | 4714 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 6618 | 1288 | 196 | 0 | 0 | 5257 | 4694 | -- | -- | -- | -- | -- | -- | -- | -- |
| 16 OCT | 53 | 12.9 | 6406 | 896 | 326 | 0 | 0 | 5475 | 4830 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 6618 | 880 | 65 | 0 | 0 | 5413 | 4743 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 6210 | 1190 | 538 | 0 | 0 | 5358 | 4592 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10 NOV | 93 | 11.5 | 4923 | 1150 | 114 | 0 | 0 | 5020 | 4121 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 1777 | 1125 | 81 | 0 | 0 | 3340 | 2321 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 4271 | 1320 | 342 | 0 | 0 | 4756 | 4070 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION D-1 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 17 AUG | 30 | 16.7 | 7465 | 1565 | 880 | 0 | 16 | 6132 | 5232 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10204 | 1532 | 1826 | 81 | 0 | 8756 | 7270 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7824 | 1826 | 896 | 0 | 0 | 8272 | 7073 | -- | -- | -- | -- | -- | -- | -- | -- |
| 17 SEPT | 30 | 15.9 | 9128 | -1 | 2233 | 16 | 0 | 7182 | 5511 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8183 | -1 | 1141 | 0 | 0 | 7646 | 5829 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 11326 | -1 | 831 | 0 | 0 | 8243 | 6976 | -- | -- | -- | -- | -- | -- | -- | -- |
| 15 OCT | 28 | 11.8 | 4287 | 782 | 603 | 0 | 16 | 5340 | 3728 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6748 | 1043 | 929 | 0 | 0 | 6331 | 4808 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7042 | 570 | 2119 | 0 | 16 | 5765 | 3930 | -- | -- | -- | -- | -- | -- | -- | -- |
| 8 NOV | 30 | 10.7 | 8565 | 1141 | 3782 | 0 | 0 | 7995 | 5666 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5200 | 701 | 945 | 0 | 0 | 5068 | 3847 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8411 | 1418 | 1239 | 49 | 0 | 7617 | 6334 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION D-2 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 14 MAY | 82 | -1.0 | -1 | 1 | -1 | -1 | -1 | -1 | -1 | 3.85 | 2.70 | .70 | 1.07 | -1 | -1 | 3071 | 1408 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.08 | 2.47 | .93 | .77 | -1 | -1 | 4134 | 1963 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.63 | 1.87 | .70 | .72 | -1 | -1 | 4025 | 1828 |
| 11 JUNE | 97 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 333 | 277 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 359 | 263 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 251 | 204 |
| 15 JULY | 113 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.93 | 3.10 | 1.93 | .50 | -1 | -1 | 564 | 489 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.20 | 3.37 | .26 | .77 | -1 | -1 | 791 | 697 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.47 | 4.03 | 1.27 | .77 | -1 | -1 | 609 | 508 |
| 17 AUG | 87 | 16.5 | 1168 | 228 | 33 | 0 | 0 | 975 | 472 | 1.43 | 1.40 | .67 | .40 | -1 | -1 | 774 | 667 |
| | | | 1157 | 293 | 0 | 16 | 0 | 877 | 794 | 2.20 | 1.23 | 1.23 | .87 | -1 | -1 | 731 | 622 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.73 | 1.23 | .47 | .50 | -1 | -1 | 763 | 659 |
| 17 SEPT | 87 | 17.5 | 3032 | 570 | 633 | 0 | 0 | 3040 | 2528 | 1.53 | 1.10 | .77 | .70 | -1 | -1 | 230 | 126 |
| | | | 3614 | 1027 | 505 | 0 | 0 | 2999 | 2531 | 1.43 | 1.17 | .70 | .60 | -1 | -1 | 335 | 160 |
| | | | 3619 | 945 | 424 | 0 | 0 | 3465 | 2897 | 1.40 | .97 | .77 | .67 | -1 | -1 | 249 | 217 |
| 15 OCT | 96 | 11.7 | 2608 | 782 | 163 | 0 | 0 | 2566 | 2036 | 1.10 | 1.13 | .80 | .57 | -1 | -1 | 65 | 37 |
| | | | 2657 | 33 | 310 | 16 | 0 | 2294 | 1751 | 1.03 | 1.27 | .77 | .37 | -1 | -1 | 58 | 38 |
| | | | 2135 | 0 | 310 | 0 | 0 | 1351 | 1040 | 1.10 | 1.47 | .67 | .83 | -1 | -1 | 58 | 41 |
| 8 NOV | 92 | 10.8 | 2363 | 407 | 277 | 0 | 0 | 1658 | 1364 | .90 | .90 | .73 | .63 | -1 | -1 | 252 | 180 |
| | | | 1820 | 326 | 196 | 0 | 0 | 1444 | 1231 | 1.03 | .97 | .63 | .70 | -1 | -1 | 278 | 207 |
| | | | 1956 | 228 | 163 | 0 | 0 | 1183 | 1011 | 1.23 | 1.07 | .67 | .53 | -1 | -1 | 296 | 210 |

STATION D-3 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 18 AUG | 172 | 18.4 | 1255 | 293 | 0 | 0 | 0 | 1500 | 1348 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1190 | 196 | 16 | 81 | 0 | 1477 | 1311 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 49 | 81 | 0 | 0 | 0 | 83 | 73 | -- | -- | -- | -- | -- | -- | -- | -- |
| 18 SEPT | 169 | 17.2 | 1206 | -1 | 16 | 16 | 0 | 1143 | 1045 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1679 | -1 | 16 | 33 | 0 | 1860 | 1692 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1108 | -1 | 16 | 0 | 0 | 1201 | 1105 | -- | -- | -- | -- | -- | -- | -- | -- |
| 15 OCT | 166 | 11.2 | 962 | 49 | 0 | 0 | 0 | 817 | 724 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1418 | 16 | 16 | 0 | 0 | 1139 | 1011 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2119 | 407 | 65 | 0 | 0 | 2000 | 1788 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9 NOV | 166 | 10.7 | 864 | 114 | 33 | 0 | 0 | 795 | 706 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 880 | 130 | 0 | 0 | 0 | 662 | 595 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 685 | 342 | 16 | 0 | 0 | 996 | 867 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION D-4 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 14 MAY | 125 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | 1.80 | -1.00 | 1.10 | -1 | -1 | 4576 | 2154 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | 1.63 | -1.00 | 1.23 | -1 | -1 | 3187 | 1736 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 3828 | 2123 |
| 11 JUNE | 147 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 623 | 548 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 660 | 574 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 662 | 572 |
| 15 JULY | 117 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.03 | .73 | .63 | .63 | -1 | -1 | 240 | 217 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .97 | .70 | .40 | .63 | -1 | -1 | 719 | 654 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .80 | 1.00 | .43 | .20 | -1 | -1 | 1070 | 1001 |
| 18 AUG | 141 | 16.4 | 2233 | 130 | 49 | 33 | 0 | 1578 | 1474 | 2.33 | .93 | .97 | .57 | -1 | -1 | 967 | 875 |
| | | | 310 | -1 | 0 | 0 | 0 | 227 | 189 | 1.83 | 1.07 | .80 | .87 | -1 | -1 | 1402 | 1283 |
| | | | 2152 | -1 | 16 | 33 | 0 | 2060 | 1834 | 2.10 | 1.00 | .90 | .33 | -1 | -1 | 1402 | 1279 |
| 18 SEPT | 125 | 17.9 | 3602 | -1 | 0 | 16 | 0 | 3033 | 2730 | 1.50 | 1.13 | .90 | .90 | -1 | -1 | 374 | 239 |
| | | | 3586 | -1 | 49 | 0 | 0 | 3529 | 3223 | 2.53 | 1.30 | .87 | .97 | -1 | -1 | 242 | 177 |
| | | | 2494 | -1 | 16 | 0 | 0 | 2408 | 2200 | 1.63 | 1.43 | .83 | .90 | -1 | -1 | 472 | 405 |
| 15 OCT | 130 | 11.3 | 2738 | 407 | 16 | 0 | 0 | 2556 | 2649 | .83 | .93 | .50 | .57 | -1 | -1 | 88 | 47 |
| | | | 2624 | 228 | 98 | 0 | 0 | 2341 | 2046 | 1.33 | .87 | .70 | .33 | -1 | -1 | 121 | 96 |
| | | | 2604 | 652 | 81 | 0 | 0 | 2898 | 2559 | 1.13 | .93 | .70 | .47 | -1 | -1 | 149 | 122 |
| 9 NOV | 124 | 9.5 | 1059 | 163 | 49 | 0 | 0 | 1205 | 1073 | .97 | .53 | .77 | .27 | -1 | -1 | 454 | 348 |
| | | | 1369 | 56 | 0 | 0 | 0 | 1632 | 1518 | 1.27 | .63 | .93 | .47 | -1 | -1 | 297 | 221 |
| | | | 1646 | 33 | 49 | 0 | 0 | 1374 | 1258 | .97 | .63 | .90 | .33 | -1 | -1 | 281 | 217 |

STATION D-5 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 14 MAY | 110 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.47 | 2.33 | .77 | 1.07 | -1 | -1 | 3855 | 2227 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.57 | 2.10 | .93 | 1.67 | -1 | -1 | 1517 | 1115 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.13 | 2.10 | 1.17 | -1.00 | -1 | -1 | 2041 | 1507 |
| 10 JUNE | 115 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | 1.00 | -1 | -1 | 345 | 285 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 575 | 395 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 583 | 468 |
| 15 JULY | 129 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.23 | 1.07 | .47 | .53 | -1 | -1 | 2158 | 1967 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.37 | 1.10 | .50 | .17 | -1 | -1 | 2630 | 2476 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.07 | 1.63 | .57 | .70 | -1 | -1 | 2150 | 1963 |
| 18 AUG | 117 | 19.7 | 3456 | -1 | 16 | 16 | 0 | 2709 | 2378 | 2.37 | 1.23 | 1.17 | .67 | -1 | -1 | 1114 | 965 |
| | | | 2526 | -1 | 33 | 0 | 0 | 1868 | 1661 | 2.07 | 1.17 | .77 | .77 | -1 | -1 | 1076 | 954 |
| | | | 3390 | -1 | 0 | 33 | 0 | 2787 | 2368 | 2.30 | .97 | 1.50 | .77 | -1 | -1 | 1111 | 979 |
| 18 SEPT | 120 | 16.7 | 2168 | -1 | 212 | 0 | 0 | 1881 | 1606 | 2.07 | 1.50 | 1.00 | .77 | -1 | -1 | -1 | -1 |
| | | | 2476 | -1 | 49 | 0 | 0 | 2474 | 2122 | 1.93 | 1.17 | 1.03 | .90 | -1 | -1 | 237 | 198 |
| | | | 2461 | -1 | 33 | 16 | 0 | 2062 | 1726 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 190 | 144 |
| 14 OCT | 116 | 10.0 | 2282 | 652 | 163 | 0 | 0 | 1816 | 1444 | 1.37 | 1.07 | .77 | .50 | -1 | -1 | 29 | 13 |
| | | | 1565 | 49 | 65 | 0 | 0 | 2117 | 1897 | 1.37 | 1.03 | .70 | .60 | -1 | -1 | 109 | 70 |
| | | | 2461 | 652 | 65 | 0 | 0 | 2830 | 2443 | 1.33 | 1.23 | .87 | .63 | -1 | -1 | 28 | 13 |
| 9 NOV | 111 | 5.3 | 2347 | 733 | 228 | 0 | 0 | 1871 | 1573 | 1.13 | 1.27 | .90 | .37 | -1 | -1 | 297 | 203 |
| | | | 1108 | 375 | 0 | 16 | 0 | 1025 | 905 | 1.33 | 1.13 | .63 | .63 | -1 | -1 | 263 | 169 |
| | | | 1728 | 147 | 65 | 0 | 0 | 945 | 830 | 1.03 | 1.00 | .70 | .47 | -1 | -1 | 341 | 237 |

STATION D-6 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 18 AUG | 29 | 19.7 | 7677 | -1 | 13562 | 130 | 0 | 11162 | 5152 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4857 | -1 | 1728 | 49 | 0 | 7532 | 4098 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10024 | -1 | 5509 | 98 | 0 | 3558 | 2593 | -- | -- | -- | -- | -- | -- | -- | -- |
| 18 SEPT | 29 | 12.8 | 9079 | 1239 | 1597 | 49 | 0 | 5633 | 4571 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 12747 | 896 | 7938 | 49 | 0 | 7941 | 4644 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 12437 | 1777 | 4531 | 98 | 0 | 8254 | 5831 | -- | -- | -- | -- | -- | -- | -- | -- |
| 14 OCT | 32 | 6.8 | 13268 | 1418 | 766 | 33 | 0 | 8593 | 6905 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 15338 | 2233 | 2200 | 33 | 16 | 10443 | 7816 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 14067 | 1271 | 1728 | 49 | 0 | 10233 | 7764 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9 NOV | 30 | 7.9 | 10041 | 1663 | 1353 | 212 | 0 | 6921 | 5604 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 13855 | 1630 | 1418 | 0 | 0 | 8512 | 6740 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION [illegible]-1 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 AUG | 44 | 10.3 | 11647 | 685 | 2070 | 49 | 0 | 13465 | 11599 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10530 | 1793 | 2722 | 81 | 0 | 12703 | 10735 | -- | -- | -- | -- | -- | -- | -- | - |
| | | | 9780 | 1369 | 1565 | 65 | 0 | 12412 | 10709 | -- | -- | -- | -- | -- | -- | -- | -- |
| 16 SEPT | 42 | 14.2 | 11524 | -1 | 2005 | 16 | 0 | 12598 | 10680 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9487 | -1 | 3227 | 0 | 0 | 7694 | 5739 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 13154 | -1 | 5118 | 33 | 0 | 13650 | 10509 | -- | -- | -- | -- | -- | -- | -- | -- |
| 12 OCT | 44 | 16.1 | 9112 | 750 | 3700 | 0 | 0 | 9865 | 7614 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10367 | 1826 | 3879 | 16 | 0 | 13400 | 10525 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10562 | 1500 | 4460 | 33 | 0 | 12152 | 9496 | -- | -- | -- | -- | -- | -- | -- | -- |
| 6 NOV | 44 | 10.0 | 7791 | 2706 | 2217 | 65 | 0 | 11426 | 8539 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9079 | 1304 | 2901 | 49 | 0 | 10471 | 8298 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9878 | 1320 | 440 | 49 | 0 | 10606 | 9449 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION E-2 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 MAY | 198 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.43 | 1.57 | 1.07 | 1.43 | -1 | -1 | 5810 | 3183 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.47 | 1.57 | 1.03 | 1.33 | -1 | -1 | 4309 | 2602 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.27 | 1.37 | .57 | -1.00 | -1 | -1 | 4784 | 1927 |
| 13 JUNE | 201 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 1887 | 1727 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 1518 | 1415 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 1163 | 1088 |
| 14 JULY | 200 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.83 | .87 | 1.13 | .80 | -1 | -1 | 1084 | 999 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.47 | 1.13 | .60 | .73 | -1 | -1 | 1067 | 993 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.53 | .80 | 1.47 | -1.00 | -1 | -1 | 1385 | 1303 |
| 15 AUG | 197 | 15.8 | 603 | -1 | 0 | 0 | 0 | 427 | 383 | 3.27 | 1.97 | 1.43 | 1.00 | -1 | -1 | 1113 | 919 |
| | | | 619 | -1 | 0 | 0 | 0 | 337 | 302 | 2.63 | 1.07 | 1.43 | .47 | -1 | -1 | 1025 | 902 |
| | | | 473 | -1 | 0 | 0 | 0 | 261 | 236 | 1.93 | .87 | .80 | .60 | -1 | -1 | 1272 | 1107 |
| 16 SEPT | 197 | 15.8 | 2347 | 701 | 0 | 0 | 0 | 2064 | 1777 | 1.73 | 1.07 | 1.23 | 1.03 | -1 | -1 | 1010 | 935 |
| | | | 2346 | 733 | 0 | 33 | 0 | 2380 | 2142 | 1.80 | .90 | 1.53 | .67 | -1 | -1 | 848 | 743 |
| | | | 1516 | 570 | 33 | 0 | 0 | 1381 | 1208 | 1.67 | .83 | 1.00 | .80 | -1 | -1 | 1596 | 1225 |
| 12 OCT | 196 | 11.6 | 1597 | 130 | 0 | 0 | 0 | 1501 | 1369 | 1.47 | 1.40 | .87 | .65 | -1 | -1 | 759 | 685 |
| | | | 1891 | 342 | 0 | 0 | 0 | 1356 | 1250 | 1.20 | 1.33 | .77 | .63 | -1 | -1 | 443 | 387 |
| | | | 2103 | 310 | 0 | 0 | 0 | 1822 | 1656 | 1.47 | 1.40 | .80 | .53 | -1 | -1 | 627 | 556 |
| 7 NOV | 196 | 5.8 | 1653 | 293 | 65 | 0 | 0 | 857 | 748 | 1.03 | .80 | .83 | .70 | -1 | -1 | 261 | 194 |
| | | | 1402 | 554 | 0 | 0 | 0 | 864 | 756 | 3.20 | .70 | .90 | .23 | -1 | -1 | 330 | 266 |
| | | | 1646 | 359 | 0 | 16 | 0 | 1118 | 1002 | 1.07 | .67 | .90 | .63 | -1 | -1 | 275 | 241 |

STATION E-3 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 MAY | 276 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.60 | .73 | 1.07 | .70 | -1 | -1 | 4394 | 3891 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.03 | .77 | .93 | .67 | -1 | -1 | 4121 | 3705 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.03 | .97 | 1.00 | .70 | -1 | -1 | 3234 | 2542 |
| 13 JUNE | 275 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 1082 | 1019 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 1060 | 1011 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 1219 | 1160 |
| 14 JULY | 274 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.47 | .60 | 1.40 | .53 | -1 | -1 | 1373 | 1236 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.93 | .27 | .33 | -1.00 | -1 | -1 | 1900 | 1640 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.23 | .47 | .37 | .23 | -1 | -1 | 1904 | 1802 |
| 15 AUG | 275 | 17.8 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.17 | .47 | .90 | .33 | -1 | -1 | 878 | 805 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.37 | .43 | .93 | .33 | -1 | -1 | 783 | 717 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.83 | .50 | .57 | .50 | -1 | -1 | 1522 | 1387 |
| 16 SEPT | 275 | 16.3 | 619 | 587 | 0 | 0 | 0 | 795 | 683 | 1.57 | .67 | .90 | .67 | -1 | -1 | 1079 | 971 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.33 | .53 | .70 | .47 | -1 | -1 | 1393 | 1266 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.63 | .60 | 1.13 | .43 | -1 | -1 | 1194 | 1071 |
| 13 OCT | 274 | 11.2 | 603 | 65 | 65 | 0 | 0 | 321 | 251 | 1.13 | .93 | .63 | .57 | -1 | -1 | 394 | 347 |
| | | | 310 | 0 | 0 | 0 | 0 | 166 | 134 | 1.00 | .60 | .53 | .33 | -1 | -1 | 402 | [illegible] |
| | | | 456 | 163 | 0 | 0 | 0 | 461 | 393 | 1.20 | .70 | .67 | .53 | -1 | -1 | [illegible] | [illegible] |
| 7 NOV | 274 | 10.0 | 619 | 58 | 0 | 0 | 0 | 556 | 416 | .77 | .37 | .70 | .30 | -1 | -1 | 231 | [illegible] |
| | | | 473 | 114 | 0 | 0 | 0 | 298 | 251 | 1.13 | .73 | 1.00 | .53 | -1 | -1 | 187 | 157 |
| | | | 310 | 0 | 0 | 0 | 0 | 129 | 119 | .97 | .33 | .67 | .27 | -1 | -1 | 239 | 199 |

STATICN E-4 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M$^2$ DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M$^2$ DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 AUG | 215 | 17.7 | 244 | 0 | 0 | 16 | 0 | 95 | 75 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 456 | 0 | 0 | 0 | 0 | 220 | 196 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 587 | 0 | 0 | 16 | 0 | 171 | 153 | -- | -- | -- | -- | -- | -- | -- | -- |
| 16 SEPT | 183 | 15.9 | 619 | -1 | 0 | 16 | 0 | 362 | 318 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 701 | -1 | 0 | 0 | 0 | 424 | 372 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 179 | -1 | 0 | 0 | 0 | 130 | 114 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 OCT | 216 | 9.5 | 733 | 0 | 0 | 0 | 0 | 572 | 509 | -- | - | -- | -- | -- | -- | -- | -- |
| | | | 717 | 16 | 0 | 0 | 0 | 403 | 362 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 782 | 0 | 0 | 0 | 0 | 437 | 403 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7 NOV | 196 | 10.3 | 212 | 0 | 0 | 0 | 0 | 132 | 104 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 342 | 0 | 0 | 0 | 0 | 210 | 179 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 424 | 0 | 0 | 0 | 0 | 161 | 132 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION E-5 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M$^2$ DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M$^2$ DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 MAY | 173 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.83 | 1.33 | 1.43 | .97 | -1 | -1 | 3750 | 2114 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.57 | 1.70 | .97 | 1.33 | -1 | -1 | 3009 | 1846 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.43 | 1.17 | .93 | .90 | -1 | -1 | 5591 | 2839 |
| 13 JUNE | 178 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 856 | 802 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 634 | 602 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1.00 | -1.00 | -1.00 | -1.00 | -1 | -1 | 771 | 731 |
| 14 JULY | 155 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.40 | .77 | .93 | .20 | -1 | -1 | 961 | 894 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.33 | .73 | .40 | .33 | -1 | -1 | 1428 | 1340 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.20 | .50 | .53 | .23 | -1 | -1 | 1166 | 1067 |
| 16 AUG | 174 | 18.0 | 1125 | 147 | 0 | 0 | 0 | 1249 | 1121 | 1.60 | .43 | .80 | .30 | -1 | -1 | 1653 | 1498 |
| | | | 619 | 33 | 0 | 16 | 0 | 696 | 665 | 1.17 | .70 | .43 | .43 | -1 | -1 | 1514 | 1424 |
| | | | 913 | 98 | 0 | 0 | 0 | 901 | 843 | 1.27 | .80 | .57 | .70 | -1 | -1 | 1432 | 1335 |
| 16 SEPT | 176 | 13.7 | 1255 | 33 | 0 | 0 | 0 | 1751 | 1641 | 1.13 | .87 | .80 | .87 | -1 | -1 | 1567 | 1421 |
| | | | 1614 | 196 | 33 | 0 | 0 | 1816 | 1669 | 1.33 | .60 | 1.10 | .55 | -1 | -1 | 1139 | 1022 |
| | | | 1304 | 244 | 0 | 0 | 0 | 1728 | 1597 | 1.40 | 1.50 | 1.17 | .83 | -1 | -1 | 1338 | 1180 |
| 13 OCT | 165 | 9.7 | 929 | 65 | 16 | 16 | 0 | 1025 | 913 | 2.00 | .67 | .90 | .40 | -1 | -1 | 764 | 690 |
| | | | 1337 | 81 | 16 | 0 | 0 | 1340 | 1200 | 1.40 | .67 | .70 | .33 | -1 | -1 | 935 | 849 |
| | | | 1402 | 0 | 33 | 0 | 0 | 1377 | 1244 | 1.27 | .73 | .90 | .47 | -1 | -1 | 937 | 87 |
| 7 NOV | 165 | 10.0 | 375 | 163 | 65 | 0 | 0 | 391 | 310 | 1.00 | .73 | .87 | .47 | -1 | -1 | 536 | 471 |
| | | | 766 | 212 | 33 | 16 | 0 | 931 | 838 | 1.70 | .60 | .77 | .37 | -1 | -1 | 306 | 271 |
| | | | 587 | 65 | 16 | 0 | 0 | 553 | 487 | 1.07 | .67 | .80 | .60 | -0 | -1 | 261 | 236 |

STATICN E-6 1964

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M$^2$ DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M$^2$ DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 AUG | 33 | 14.3 | 8557 | -1 | 896 | 16 | 0 | 5066 | 4408 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4580 | -1 | 1206 | 0 | 0 | 6572 | 5617 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 12016 | -1 | 2478 | 49 | 0 | 9283 | 7553 | -- | -- | -- | -- | -- | - | -- | -- |
| 17 SEPT | 33 | 13.5 | 11622 | 945 | 4841 | 16 | 0 | 7695 | 6008 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 15941 | 1500 | 8769 | 0 | 0 | 11945 | 8942 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 14181 | 1304 | 7775 | 49 | 0 | 10235 | 6986 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 OCT | 38 | 9.3 | 9552 | 636 | 1076 | 0 | 0 | 9547 | 7340 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 19707 | 1907 | 7188 | 0 | 16 | 14375 | 9705 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10970 | 2217 | 4613 | 0 | 0 | 10430 | 7454 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7 NOV | 33 | 8.8 | 8965 | 1793 | 2445 | 114 | 0 | 8924 | 6727 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 14214 | 1320 | 7237 | 244 | 16 | 12916 | 9446 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10269 | 2722 | 7123 | 326 | 33 | 11355 | 6013 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION A-1 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN $MG/M^2$ DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK $MG/M^2$ DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 MAY | 17 | 7.6 | 456 | 277 | 49 | 33 | 0 | 1317 | 367 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 81 | 98 | 16 | 16 | 0 | 130 | 59 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 33 | 261 | 0 | 16 | 0 | 103 | 64 | -- | -- | -- | -- | -- | -- | -- | -- |
| 3 JUNE | 18 | 13.8 | 293 | 98 | 33 | 65 | 49 | 204 | 139 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 98 | 0 | 0 | 0 | 0 | 10 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 522 | 65 | 33 | 33 | 0 | 103 | 86 | -- | -- | -- | -- | -- | -- | -- | -- |
| 2 JULY | 18 | 18.1 | 108 | 258 | 0 | 22 | 22 | 69 | 37 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1312 | 151 | 86 | 43 | 22 | 711 | 151 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2322 | 538 | 86 | 43 | 22 | 2301 | 688 | -- | -- | -- | -- | -- | -- | -- | -- |
| 16 JULY | 17 | 21.5 | 581 | 1054 | 22 | 22 | 43 | 1260 | 548 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4816 | 1054 | 22 | 86 | 0 | 1210 | 931 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3505 | 602 | 22 | 86 | 0 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 AUG | 17 | 21.0 | 4365 | 1613 | 215 | 43 | 0 | 4139 | 2096 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4451 | 2516 | 495 | 86 | 0 | 3726 | 2371 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1011 | 559 | 0 | 22 | 0 | 774 | 531 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10 SEPT | 19 | 18.3 | 2408 | 3658 | 1161 | 65 | 22 | 4532 | 2023 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2602 | 2752 | 1161 | 0 | 43 | 6061 | 1838 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2430 | 2023 | 1032 | 0 | 22 | 12522 | 3507 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 OCT | 17 | 12.9 | 65 | 308 | 43 | 0 | 0 | 353 | 198 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 65 | 258 | 0 | 0 | 0 | 159 | 90 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 54 | 452 | 0 | 22 | 151 | 645 | 529 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5 NOV | 18 | 11.2 | 516 | 581 | 129 | 86 | 43 | 1965 | 714 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 538 | 1290 | 344 | 43 | 22 | 4304 | 3025 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 774 | 774 | 86 | 86 | 0 | 1090 | 875 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION A-2 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN $MG/M^2$ DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK $MG/M^2$ DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 MAY | 43 | 3.3 | 4857 | 5656 | 2184 | 570 | 16 | 11143 | 6763 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4645 | 5672 | 3733 | 228 | 0 | 9640 | 5672 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3798 | 7319 | 2592 | 147 | 0 | 8963 | 5275 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 JUNE | 32 | 12.8 | 5685 | 6341 | 5379 | 98 | 0 | 23267 | 11247 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5786 | 4955 | 12241 | 228 | 0 | 16688 | 8939 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6781 | 3684 | 9650 | 130 | 33 | 16194 | 5654 | -- | -- | -- | -- | -- | -- | -- | -- |
| 2 JULY | 34 | 17.3 | 5160 | 7525 | 9761 | 237 | 0 | 15701 | 5198 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6493 | 8213 | 4838 | 108 | 0 | 16260 | 10382 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5848 | 7396 | 8022 | 129 | 22 | 18737 | 11539 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 JULY | 35 | 20.8 | 2559 | 4558 | 2537 | 151 | 0 | 8637 | 579 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2602 | 5913 | 3462 | 215 | 0 | 10288 | 6820 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2580 | 4967 | 4386 | 43 | 0 | 8830 | 5680 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 AUG | 32 | 20.1 | 9576 | 15760 | 9525 | 237 | 0 | 27557 | 18714 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10643 | 8794 | 7955 | 344 | 0 | 28692 | 18862 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 11073 | 8729 | 11438 | 215 | 0 | 25035 | 15693 | -- | -- | -- | -- | -- | -- | -- | -- |
| 18 SEPT | 36 | 18.5 | 4322 | 12449 | 5528 | 0 | 0 | 12816 | 8265 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4085 | 4322 | 5504 | 237 | 0 | 13003 | 9400 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4924 | 10213 | 4773 | 86 | 0 | 13111 | 8452 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 OCT | 32 | 13.4 | 8536 | 6665 | 5547 | 43 | 0 | 21330 | 13096 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9288 | 7547 | 7740 | 65 | 22 | 23543 | 15117 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7117 | 7181 | 6300 | 0 | 0 | 17763 | 10440 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5 NOV | 35 | 10.3 | 8585 | 9073 | 6601 | 194 | 0 | 18776 | 11346 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7181 | 14513 | 6988 | 43 | 0 | 19208 | 11694 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9669 | 11395 | 6923 | 22 | 0 | 19245 | 11780 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION A-3 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | DRY | | ASH FREE | | | | | |
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 4 MAY | 71 | 2.1 | 5363 | 1157 | 1385 | 261 | 0 | 4509 | 3430 | 3.83 | 2.27 | 1.80 | 1.30 | 158 | 153 | 529 | 456 |
| | | | 5216 | 1255 | 1581 | 130 | 0 | 4377 | 3384 | 2.63 | 1.97 | 1.03 | 1.00 | 173 | 180 | 506 | 426 |
| | | | 4026 | 1565 | 1043 | 114 | 0 | 3232 | 2515 | 2.23 | 1.97 | 1.10 | .73 | 170 | 148 | 774 | 697 |
| 19 MAY | 67 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.67 | 3.17 | .47 | 2.33 | 169 | 171 | 489 | 431 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.80 | 2.20 | .50 | .97 | 146 | 176 | 282 | 189 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.73 | 1.83 | .50 | .57 | 164 | 188 | 659 | 607 |
| 4 JUNE | 66 | 9.6 | 5265 | 473 | 1532 | 58 | 0 | 5037 | 3954 | 1.60 | 1.83 | .87 | .77 | 156 | 165 | 764 | 642 |
| | | | 5151 | 1271 | 1320 | 156 | 0 | 4883 | 3938 | 2.10 | 2.00 | 1.07 | .87 | 175 | 204 | 470 | 404 |
| | | | 5509 | 326 | 1418 | 147 | 0 | 5819 | 4742 | 1.93 | 1.97 | .90 | .83 | 262 | 187 | 552 | 450 |
| 2 JULY | 67 | 16.9 | 5397 | 1011 | 1785 | 215 | 22 | 5098 | 3864 | 1.67 | .83 | 1.10 | .40 | 155 | 154 | 605 | 517 |
| | | | 4451 | 667 | 1097 | 258 | 22 | 3932 | 3057 | 1.63 | 1.03 | .67 | .47 | 158 | 161 | 586 | 495 |
| | | | 3892 | 409 | 2043 | 280 | 0 | 3881 | 2890 | 1.57 | 1.00 | .77 | .60 | 150 | 159 | 738 | 552 |
| 16 JULY | 67 | 20.8 | 4666 | 2000 | 753 | 172 | 0 | 5915 | 4863 | 2.07 | 1.07 | .90 | .50 | 176 | 170 | 533 | 507 |
| | | | 4322 | 3290 | 925 | 172 | 0 | 6585 | 5369 | 2.37 | 2.10 | .97 | .97 | 164 | 176 | 468 | 436 |
| | | | 5249 | 3182 | 1097 | 430 | 0 | 6482 | 5298 | 2.00 | 1.33 | 1.27 | .53 | 173 | 170 | 362 | 343 |
| 13 AUG | 66 | 19.2 | 5461 | 2903 | 1398 | 258 | 0 | 5588 | 4466 | 1.93 | 3.53 | .87 | 1.07 | 193 | 180 | 1249 | 1155 |
| | | | 5483 | 2516 | 2086 | 280 | 0 | 5704 | 4457 | 1.97 | 3.60 | .80 | .93 | 202 | 209 | 669 | 619 |
| | | | 22 | 1054 | 0 | 22 | 0 | 398 | 99 | 2.03 | 3.40 | .80 | 1.07 | 197 | 198 | 846 | 778 |
| 18 SEPT | 76 | 18.9 | 4085 | 1742 | 817 | 0 | 0 | 4517 | 3565 | 2.43 | 2.13 | .77 | .87 | 151 | 154 | 435 | 384 |
| | | | 5096 | 2193 | 602 | 43 | 0 | 6919 | 5027 | 2.40 | 2.07 | 1.07 | .87 | 148 | 164 | 329 | 292 |
| | | | 4945 | 1957 | 796 | 0 | 0 | 5588 | 4371 | 2.57 | 2.50 | .93 | .80 | 150 | 154 | 335 | 281 |
| 13 OCT | 65 | 13.9 | 4601 | 3354 | 1548 | 0 | 22 | 7226 | 5203 | 1.93 | 2.53 | 1.50 | 1.27 | 165 | 170 | 855 | 767 |
| | | | 5311 | 2709 | 1376 | 0 | 0 | 5652 | 4145 | 2.43 | 1.67 | 1.33 | .73 | 159 | 170 | 1165 | 1061 |
| | | | 4064 | 2150 | 1161 | 0 | 0 | 5483 | 4096 | 2.27 | 2.63 | 1.23 | .87 | 188 | 168 | 844 | 745 |
| 5 NOV | 66 | 10.9 | 5053 | 1852 | 1183 | 43 | 0 | 4526 | 3395 | 2.47 | 2.50 | 2.00 | 1.57 | 164 | 159 | 169 | 140 |
| | | | 6622 | 3118 | 2301 | 22 | 0 | 5790 | 4165 | 2.03 | 2.37 | 1.37 | 1.73 | 157 | 155 | 278 | 249 |
| | | | 4623 | 1656 | 1376 | 0 | 0 | 4803 | 3167 | 2.13 | 1.97 | 1.60 | 1.40 | 167 | 153 | 410 | 366 |

STATION A-4 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | DRY | | ASH FREE | | | | | |
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 4 MAY | 71 | 2.4 | 6079 | 146 | 565 | 400 | 0 | 3847 | 3183 | 2.27 | 2.10 | 1.17 | .90 | 154 | 162 | 452 | 335 |
| | | | 2946 | 127 | 740 | 146 | 0 | 2550 | 2146 | 2.07 | 1.80 | .93 | .83 | 179 | 213 | 622 | 569 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.90 | 1.70 | .67 | -1.00 | 154 | 150 | 399 | 353 |
| 19 MAY | 75 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.83 | 1.93 | .63 | 1.20 | 175 | 181 | 603 | 228 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.77 | 1.73 | .87 | .63 | 179 | 185 | 328 | 297 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.20 | 1.80 | .90 | .87 | 158 | 153 | 360 | 324 |
| 4 JUNE | 72 | 6.3 | 3407 | 33 | 831 | 130 | 0 | 3430 | 2849 | 1.73 | 1.70 | .93 | .87 | 189 | 191 | 699 | 525 |
| | | | 3130 | 33 | 636 | 212 | 0 | 2603 | 2016 | 1.60 | 1.57 | .87 | .67 | 162 | 173 | 859 | 656 |
| | | | 3993 | 33 | 880 | 310 | 0 | 3728 | 3100 | 1.60 | 1.63 | .83 | .67 | 170 | 174 | 616 | 501 |
| 1 JULY | 73 | 15.2 | 3677 | 129 | 258 | 86 | 0 | 3872 | 3184 | 1.60 | 1.20 | 1.03 | .63 | 181 | 162 | 520 | 459 |
| | | | 2752 | 65 | 237 | 108 | 0 | 2303 | 1892 | 1.43 | 1.13 | .73 | .77 | 161 | 166 | 717 | 605 |
| | | | 1097 | 22 | 323 | 22 | 0 | 675 | 454 | 1.40 | 1.10 | .90 | .60 | 162 | 226 | 322 | 253 |
| 16 JULY | 74 | 20.6 | 3978 | 301 | 409 | 129 | 0 | 3373 | 2834 | 2.40 | 1.33 | 1.27 | .57 | 165 | 173 | 485 | 463 |
| | | | 3720 | 455 | 237 | 65 | 0 | 3255 | 2799 | 2.30 | -1.00 | 1.23 | -1.00 | 202 | 215 | 1266 | 1210 |
| | | | 3376 | 538 | 108 | 151 | 0 | 2672 | 2305 | 2.40 | 1.43 | 1.33 | .63 | 184 | 172 | 806 | 776 |
| 14 AUG | 74 | 20.5 | 4859 | 581 | 667 | 172 | 0 | 4420 | 3687 | 1.80 | 2.07 | .43 | .67 | 198 | 190 | [illegible] | 656 |
| | | | 4322 | 258 | 602 | 129 | 0 | 3032 | 2511 | 2.50 | [illegible] | .97 | .77 | 204 | 200 | [illegible] | 807 |
| | | | 4150 | 43 | 258 | 151 | 0 | 3363 | 2918 | 2.20 | [illegible] | 1.00 | .63 | 197 | 190 | 929 | 865 |
| 18 SEPT | 73 | 15.2 | 4580 | 387 | 237 | 43 | 0 | 2946 | 2460 | 2.20 | 2.33 | .87 | .97 | 146 | 153 | 240 | 214 |
| | | | 3999 | 194 | 323 | 0 | 0 | 2629 | 2264 | 2.17 | 2.73 | .80 | 1.07 | 143 | 153 | 243 | 216 |
| | | | 5074 | 43 | 215 | 22 | 0 | 3285 | 2862 | 2.30 | 2.50 | .83 | .60 | 154 | 158 | 334 | 296 |
| 14 OCT | 73 | -1.0 | 4537 | 7181 | 387 | 43 | 22 | 3677 | 3219 | 3.60 | 1.77 | 1.70 | 1.03 | 163 | 156 | 773 | 662 |
| | | | 4515 | 237 | 645 | 0 | 22 | 3182 | 2821 | 2.37 | 1.53 | 1.07 | .53 | 144 | 154 | 732 | 654 |
| | | | 4795 | 258 | 280 | 22 | 0 | 3158 | 2589 | 1.50 | 2.37 | .80 | .83 | 146 | 149 | 734 | 623 |
| 5 NOV | 72 | 10.9 | 3526 | 581 | 258 | 0 | 0 | 3016 | 2608 | 1.53 | 2.47 | 1.17 | 1.87 | [illegible] | 151 | 168 | 147 |
| | | | 3698 | 409 | 301 | 0 | 0 | 2464 | 2148 | 1.53 | 2.13 | 1.10 | 1.63 | 147 | 148 | 333 | 299 |
| | | | 3999 | 430 | 344 | 0 | 0 | 2801 | 2453 | 1.70 | 1.97 | 1.27 | 1.43 | 152 | 156 | 62 | 42 |

STATION A-5 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L |  |  |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M² |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 4 MAY | 44 | 3.0 | 4023 | 1602 | 728 | 273 | 0 | 4736 | 3815 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 4969 | 1583 | 1250 | 309 | 0 | 4978 | 3979 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 JUNE | 43 | 7.5 | 3586 | 505 | 1500 | 163 | 0 | 3899 | 3165 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 2608 | 685 | 1157 | 114 | 0 | 3454 | 2724 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 1304 | 156 | 962 | 49 | 0 | 1760 | 1324 | -- | -- | -- | -- | -- | -- | -- | -- |
| 30 JUNE | 41 | 17.2 | 2774 | 1054 | 2150 | 237 | 0 | 2471 | 2318 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 1312 | 1204 | 86 | 43 | 0 | 1843 | 1595 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 5010 | 1849 | 2537 | 108 | 0 | 6558 | 5083 | -- | -- | -- | -- | -- | -- | -- | -- |
| 16 JULY | 44 | 20.2 | 5203 | 1376 | 1011 | 43 | 0 | 4947 | 4156 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | -1 | -1 | -1 | -1 | -1 | 5139 | 3982 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 9030 | 1828 | 3247 | 194 | 0 | 4328 | 3395 | -- | -- | -- | -- | -- | -- | -- | -- |
| 14 AUG | 43 | 21.7 | 5461 | 1462 | 1011 | 0 | 0 | 4915 | 4100 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 6235 | 2107 | 1570 | 22 | 22 | 8712 | 6745 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 3935 | 1226 | 581 | 65 | 0 | 4964 | 4124 | -- | -- | -- | -- | -- | -- | -- | -- |
| 18 SEPT | 40 | 15.0 | 9611 | 2454 | 1634 | 0 | 0 | 6852 | 5134 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 9245 | 3225 | 1376 | 0 | 22 | 7643 | 6452 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 8213 | 2344 | 1548 | 43 | 0 | 7854 | 6295 | -- | -- | -- | -- | -- | -- | -- | -- |
| 14 OCT | 41 | 12.7 | 7181 | 1634 | 581 | 0 | 22 | 6628 | 5592 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 6493 | 2454 | 731 | 43 | 22 | 6969 | 5332 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 4343 | 1140 | 22 | 22 | 22 | 4285 | 3902 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5 NOV | 42 | 10.9 | 7864 | 2279 | 1140 | 258 | 0 | 5304 | 4468 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 5332 | 2924 | 1220 | 237 | 0 | 5665 | 4760 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 8106 | 2086 | 1204 | 215 | 0 | 8211 | 6676 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION A-6 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L |  |  |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M² |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 4 MAY | 15 | 6.5 | 43 | 108 | 86 | 18 | 0 | 328 | 135 | 4.43 | -1.00 | 1.83 | -1.00 | 160 | -1 | 133 | 98 |
|  |  |  | 0 | 728 | 0 | 16 | 0 | 391 | 280 | 3.53 | -1.00 | -1.00 | -1.00 | 164 | -1 | 87 | 77 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 4.63 | -1.00 | -1.00 | -1.00 | 152 | -1 | 85 | 67 |
| 15 MAY | 18 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.03 | -1.00 | 1.70 | -1.00 | 150 | -1 | 33 | 24 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.85 | -1.00 | 1.60 | -1.00 | 138 | -1 | 20 | -1 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.25 | -1.00 | 1.80 | -1.00 | 169 | -1 | 19 | -1 |
| 4 JUNE | 18 | 11.3 | 261 | 61 | 16 | 0 | 0 | 47 | 20 | 2.50 | -1.00 | 1.50 | -1.00 | 183 | -1 | 76 | 24 |
|  |  |  | 1046 | 81 | 576 | 49 | 0 | 1461 | 290 | 2.50 | -1.00 | 1.60 | -1.00 | 174 | -1 | 104 | 28 |
|  |  |  | 130 | 81 | 0 | 0 | 16 | 129 | 114 | 2.33 | -1.00 | 1.40 | -1.00 | 174 | -1 | 67 | 24 |
| 1 JULY | 18 | 17.5 | 473 | 129 | 22 | 22 | 0 | 864 | 200 | 2.20 | -1.00 | 1.27 | -1.00 | 140 | -1 | 71 | 44 |
|  |  |  | 7654 | 151 | 357 | 0 | 0 | 5209 | 1006 | 2.23 | -1.00 | 1.37 | -1.00 | 138 | -1 | 26 | 16 |
|  |  |  | 2577 | 0 | 65 | 0 | 0 | 443 | 185 | 2.30 | -1.00 | 1.40 | -1.00 | 159 | -1 | 28 | 19 |
| 14 AUG | 18 | 26.0 | 0 | 43 | 0 | 22 | 0 | 13 | 8774 | 1.43 | -1.00 | .83 | -1.00 | 144 | -1 | 82 | 68 |
|  |  |  | 323 | 86 | 0 | 0 | 0 | 34 | 3438 | 1.83 | -1.00 | .77 | -1.00 | 148 | -1 | 70 | 63 |
|  |  |  | 86 | 43 | 22 | 0 | 0 | 32 | 17194 | 3.00 | -1.00 | 1.57 | -1.00 | 198 | -1 | 41 | 37 |
| 16 JULY | 19 | 21.5 | 6816 | 2451 | 2043 | 108 | 323 | 22184 | 9 | 1.90 | -1.00 | .97 | -1.00 | 200 | -1 | 75 | 66 |
|  |  |  | 43 | 1505 | 648 | 43 | 172 | 11096 | 30 | 1.87 | -1.00 | 1.00 | -1.00 | 189 | -1 | 63 | 55 |
|  |  |  | 22 | 17602 | 3513 | 22 | 473 | 36322 | 15 | 1.67 | -1.00 | 1.23 | -1.00 | 199 | -1 | 128 | 116 |
| 18 SEPT | 19 | 16.3 | 1415 | 65 | 0 | 22 | 0 | 678 | 518 | 2.43 | -1.00 | .97 | -1.00 | 176 | -1 | 42 | 29 |
|  |  |  | 1032 | 280 | 22 | 0 | 0 | 361 | 301 | 2.60 | -1.00 | 1.40 | -1.00 | 185 | -1 | 32 | 23 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.37 | -1.00 | .87 | -1.00 | 155 | -1 | 46 | 35 |
| 14 OCT | 17 | 12.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 4.40 | -1.00 | 2.80 | -1.00 | 179 | -1 | 458 | 349 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.10 | -1.00 | 1.53 | -1.00 | 169 | -1 | 241 | 163 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.97 | -1.00 | 1.30 | -1.00 | 167 | -1 | 183 | 128 |
| 5 NOV | 16 | 10.1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.13 | -1.00 | 2.47 | -1.00 | 82 | -1 | 43 | 25 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 5.03 | -1.00 | 2.93 | -1.00 | 153 | -1 | 30 | 20 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.87 | -1.00 | 1.97 | -1.00 | 148 | -1 | 89 | 58 |

STATION B-1 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 MAY | 18 | 6.0 | 978 | 65 | 1679 | 81 | 0 | 6108 | 1387 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2168 | 954 | 1760 | 81 | 0 | 12355 | 2608 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2119 | 668 | 1337 | 65 | 0 | 8300 | 2337 | -- | -- | -- | -- | -- | -- | -- | -- |
| 3 JUNE | 25 | 12.1 | 8085 | 1271 | 1043 | 33 | 0 | 14042 | 11906 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7694 | 1011 | 3814 | 49 | 0 | 12872 | 10111 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7922 | 326 | 4078 | 16 | 0 | 15420 | 11710 | -- | -- | -- | -- | -- | -- | -- | -- |
| 2 JULY | 27 | 16.9 | 6063 | 387 | 602 | 129 | 0 | 7863 | 6800 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6493 | 473 | 2021 | 0 | 0 | 12320 | 8297 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7657 | 495 | 688 | 151 | 22 | 9722 | 8447 | -- | -- | -- | -- | -- | -- | -- | -- |
| 14 JULY | 20 | 20.1 | 10084 | 7590 | 2301 | 215 | 0 | 15076 | 7329 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8514 | 7504 | 2193 | 86 | 22 | 22007 | 8497 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 12836 | 6988 | 2838 | 194 | 43 | 18608 | 8613 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 AUG | 19 | -1.0 | 8514 | 108 | 1247 | 129 | 22 | 4236 | 2642 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9396 | 151 | 559 | 151 | 43 | 8321 | 3735 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6515 | 280 | 817 | 215 | 65 | 3489 | 2227 | -- | -- | -- | -- | -- | -- | -- | -- |
| 19 SEPT | 20 | 18.8 | 8450 | 11395 | 2365 | 0 | 43 | 29885 | 9088 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10987 | 5956 | 2365 | 22 | 0 | 21552 | 8241 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10471 | 10535 | 3053 | 43 | 22 | 24790 | 9217 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 OCT | 18 | 13.3 | 11159 | 688 | 667 | 65 | 0 | 15553 | 9243 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6085 | 172 | 215 | 0 | 0 | 4126 | 3623 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6493 | 237 | 258 | 0 | 0 | 4276 | 3623 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 NOV | 19 | 12.0 | 3913 | 710 | 1204 | 22 | 22 | 7850 | 3810 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8944 | 7848 | 3655 | 215 | 43 | 30541 | 12965 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2623 | 10750 | 1849 | 65 | 129 | 21870 | 7983 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION B-2 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 MAY | 45 | 5.1 | 4466 | 2526 | 3977 | 326 | 0 | 7056 | 5082 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5505 | 2412 | 3244 | 424 | 0 | 7262 | 5579 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |
| 3 JUNE | 55 | 10.9 | 9144 | 685 | 4211 | 342 | 0 | 8789 | 6781 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6764 | 652 | 3488 | 522 | 0 | 6018 | 5614 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7657 | 1174 | 4454 | 440 | 0 | 9236 | 6634 | -- | -- | -- | -- | -- | -- | -- | -- |
| 2 JULY | 50 | 16.7 | 6902 | 1204 | 4300 | 108 | 0 | 8667 | 6072 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10277 | 387 | 7743 | 280 | 0 | 13321 | 9168 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6730 | 1484 | 4623 | 405 | 0 | 9183 | 6306 | -- | -- | -- | -- | -- | -- | -- | -- |
| 14 JULY | 46 | 15.1 | 5182 | 2731 | 5269 | 405 | 0 | 10808 | 7523 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5500 | 3053 | 4472 | 366 | 0 | 11958 | 9168 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2107 | 559 | 2731 | 301 | 0 | 4029 | 2518 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 AUG | 44 | 17.8 | 4924 | 3440 | 4300 | 151 | 0 | 12300 | 8824 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6386 | 3311 | 5612 | 65 | 22 | 13934 | 10320 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6235 | 4171 | 5160 | 65 | 0 | 13992 | 10576 | -- | -- | -- | -- | -- | -- | -- | -- |
| 15 SEPT | 47 | 18.8 | 5504 | 2559 | 1402 | 0 | 0 | 11616 | 9226 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1355 | 2193 | 710 | 0 | 0 | 3494 | 2498 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5655 | 4128 | 4085 | 0 | 0 | 11442 | 8443 | -- | -- | -- | -- | -- | -- | -- | -- |
| 11 OCT | 48 | 13.9 | 5956 | 2107 | 3440 | 22 | 0 | 9937 | 6690 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5547 | 2301 | 2688 | 0 | 0 | 9514 | 6527 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5741 | 3139 | 3397 | 0 | 22 | 9774 | 7129 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 NOV | 47 | 12.0 | 5633 | 3311 | 3505 | 108 | 0 | 10480 | 7815 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5784 | 280 | 4064 | 43 | 0 | 10509 | 7086 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5526 | 3866 | 4902 | 22 | 22 | 9504 | 6530 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION E-3 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L |  |  |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M² |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 3 MAY | 54 | 2.6 | 6570 | 2093 | 2311 | 273 | 0 | 6530 | 5092 | 3.33 | 3.10 | 1.17 | 1.03 | 152 | 167 | 440 | 380 |
|  |  |  | 6170 | 1438 | 2694 | 182 | 0 | 6565 | 5056 | 2.97 | 2.70 | 1.17 | 1.03 | 143 | 168 | 424 | 375 |
|  |  |  | 5860 | 1729 | 2402 | 346 | 0 | 6030 | 4921 | 2.87 | 2.60 | 1.20 | .83 | 176 | 165 | 367 | 322 |
| 18 MAY | 66 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.87 | 2.17 | .80 | 1.13 | 128 | 166 | 145 | 125 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.03 | 1.97 | 1.60 | .57 | 136 | 187 | 524 | 451 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.20 | 1.80 | .93 | .40 | 177 | 174 | 891 | 731 |
| 3 JUNE | 70 | 7.5 | 5477 | 962 | 1190 | 0 | 0 | 4673 | 3715 | 1.27 | 1.77 | .50 | .63 | 189 | 199 | 653 | 575 |
|  |  |  | 1532 | 16 | 1157 | 33 | 0 | 1628 | 518 | 1.87 | 1.33 | 1.10 | .63 | 182 | 206 | 634 | 504 |
|  |  |  | 4760 | 880 | 1679 | 782 | 0 | 5234 | 3597 | 1.20 | 1.77 | .40 | .73 | 182 | 190 | 696 | 548 |
| 2 JULY | 63 | 16.7 | 5160 | 1806 | 1548 | 516 | 0 | 5590 | 4281 | 1.83 | 2.23 | 1.10 | .70 | 141 | 182 | 645 | 521 |
|  |  |  | 3053 | 280 | 860 | 86 | 0 | 3010 | 2178 | 1.90 | 1.50 | 1.23 | .73 | 178 | 172 | 1030 | 928 |
|  |  |  | 3505 | 129 | 1505 | 43 | 0 | 2821 | 2120 | 1.93 | 2.37 | 1.20 | .77 | 172 | 181 | 753 | 640 |
| 14 JULY | 58 | 19.1 | 4816 | 2172 | 1806 | 86 | 0 | 4627 | 3606 | 2.43 | 1.97 | 1.33 | .97 | 194 | 200 | -1 | -1 |
|  |  |  | 4838 | 1720 | 1290 | 108 | 0 | 4616 | 3720 | 2.73 | 1.90 | 1.57 | .83 | 175 | 188 | 841 | 798 |
|  |  |  | 4666 | 1333 | 1226 | 108 | 0 | 4528 | 3603 | 2.10 | 2.57 | 1.20 | 1.07 | 182 | 176 | 985 | 931 |
| 13 AUG | 55 | 18.7 | 3526 | 1527 | 860 | 0 | 22 | 3782 | 3111 | 1.70 | 4.13 | .73 | .83 | 189 | 172 | 2046 | 1903 |
|  |  |  | 4769 | 1720 | 2494 | 65 | 0 | 5199 | 3900 | 1.97 | 4.07 | .80 | .90 | 192 | 193 | 982 | 922 |
|  |  |  | 430 | 1591 | 344 | 0 | 0 | 1054 | 817 | 1.37 | 4.00 | .57 | .80 | 202 | 198 | 1940 | 1794 |
| 15 SEPT | 63 | 18.4 | 4343 | 1806 | 1011 | 0 | 0 | 4489 | 3642 | 2.43 | 2.70 | .77 | .90 | 134 | 158 | 219 | 187 |
|  |  |  | 3419 | 1441 | 1247 | 0 | 0 | 3462 | 2728 | 2.17 | 3.03 | .83 | 1.13 | 152 | 154 | 231 | 207 |
|  |  |  | 3075 | 2430 | 1505 | 0 | 0 | 3608 | 2896 | 2.33 | 2.90 | .80 | 2.40 | 145 | 168 | 322 | 290 |
| 11 OCT | 62 | 14.1 | 2617 | 1871 | 1161 | 22 | 0 | 3236 | 2522 | 3.23 | 2.30 | 1.67 | .97 | 154 | 162 | 802 | 726 |
|  |  |  | 4064 | 1312 | 946 | 0 | 0 | 3732 | 3100 | 2.93 | 2.50 | 1.47 | .93 | 152 | 165 | 730 | 669 |
|  |  |  | 3655 | 2000 | 1032 | 0 | 0 | 4018 | 3281 | 2.57 | 2.23 | 1.10 | 1.00 | 159 | 164 | 307 | 281 |
| 4 NOV | 58 | 12.0 | 3806 | 1398 | 1570 | 0 | 0 | 3758 | 2774 | -1.00 | 2.93 | -1.00 | 1.80 | 144 | 164 | 300 | 251 |
|  |  |  | 3333 | 1699 | 1075 | 22 | 0 | 3661 | 2877 | 1.57 | 2.07 | .80 | 1.50 | 145 | 148 | 118 | 99 |
|  |  |  | 3763 | 1828 | 1505 | 22 | 0 | 3922 | 2582 | 1.90 | 1.47 | 1.53 | 1.27 | 132 | 145 | 279 | 246 |

STATION E-4 1565

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L |  |  |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M² |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 3 MAY | 119 | 2.3 | 2148 | 510 | 164 | 55 | 0 | 1760 | 1438 | 3.50 | 2.97 | 1.07 | 1.10 | 152 | 158 | 587 | 531 |
|  |  |  | 5515 | 473 | 36 | 164 | 0 | 1685 | 1469 | 2.77 | 1.93 | .87 | 1.00 | 170 | 186 | 613 | 558 |
|  |  |  | 3003 | 237 | 55 | 109 | 0 | 1780 | 1474 | 2.17 | 2.17 | .83 | .93 | 168 | 194 | 634 | 579 |
| 18 MAY | 119 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.33 | 1.33 | .90 | .47 | 170 | 128 | 687 | 578 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.67 | 1.67 | .80 | .90 | 107 | 135 | 201 | 174 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.67 | -1.00 | .83 | -1.00 | 206 | 182 | 540 | 466 |
| 3 JUNE | 131 | 3.6 | 1695 | 98 | 49 | 16 | 0 | 1413 | 1209 | 1.43 | 1.30 | .40 | .30 | 174 | 182 | 629 | 556 |
|  |  |  | 2363 | 913 | 33 | 49 | 0 | 2240 | 1954 | 1.37 | 1.27 | .60 | .60 | 189 | 184 | 1032 | 898 |
|  |  |  | 2054 | 49 | 0 | 0 | 0 | 1786 | 1594 | 1.13 | 1.50 | .67 | .83 | 181 | 196 | 859 | 734 |
| 1 JULY | 131 | 14.3 | 1376 | 154 | 43 | 0 | 0 | 998 | 871 | .97 | .97 | .53 | .40 | 175 | 184 | 709 | 635 |
|  |  |  | 473 | 22 | 108 | 0 | 0 | 460 | 329 | 1.00 | 1.00 | .50 | .63 | 178 | 196 | 573 | 494 |
|  |  |  | 882 | 22 | 65 | 0 | 0 | 525 | 434 | 1.10 | 1.17 | .80 | .67 | 194 | 164 | 463 | 408 |
| 14 JULY | 115 | 17.0 | 3053 | 860 | 323 | 22 | 0 | 3401 | 2847 | 1.57 | 1.00 | .80 | .77 | 203 | 133 | 790 | 725 |
|  |  |  | 2602 | 667 | 280 | 86 | 22 | 3055 | 2647 | 1.67 | 1.13 | .83 | .73 | 116 | 158 | 787 | 754 |
|  |  |  | 2946 | 624 | 65 | 22 | 0 | 2589 | 2288 | 1.67 | 1.53 | .90 | .70 | 171 | 149 | 857 | 815 |
| 12 AUG | 135 | 19.7 | 1011 | 108 | 22 | 0 | 0 | 879 | 796 | 1.70 | .73 | .63 | .47 | 192 | 197 | 1799 | 1713 |
|  |  |  | 4429 | 645 | 65 | 22 | 0 | 3070 | 2629 | 1.77 | .77 | .57 | .13 | 204 | 206 | 986 | 920 |
|  |  |  | 3741 | 753 | 86 | 0 | 0 | 4091 | 3500 | 1.60 | .63 | .50 | .27 | 200 | -1 | 1900 | 1796 |
| 17 SEPT | 122 | 18.5 | -1 | -1 | -1 | -1 | -1 | 2522 | 2245 | 2.47 | 1.97 | .77 | .83 | 157 | 170 | 828 | 773 |
|  |  |  | 1978 | 366 | 22 | 22 | 0 | 2414 | 2167 | 2.83 | 1.57 | 1.37 | .47 | 158 | 181 | 753 | 704 |
|  |  |  | 2387 | 473 | 43 | 0 | 0 | 2915 | 2569 | 2.27 | 1.83 | .80 | 1.17 | 162 | 157 | 768 | 720 |
| 15 OCT | 130 | -1.0 | 3311 | 473 | 22 | 0 | 0 | 2483 | 2301 | 1.37 | 2.00 | .97 | 1.00 | 144 | 173 | 873 | 766 |
|  |  |  | 2623 | 624 | 22 | 65 | 0 | 2879 | 2543 | 1.63 | 1.57 | .97 | .80 | 154 | 154 | 726 | 671 |
|  |  |  | 2989 | 473 | 86 | 0 | 0 | 2851 | 2541 | .33 | 1.53 | -1.00 | .57 | 152 | 169 | 506 | 460 |
| 6 NOV | 128 | 11.1 | 2066 | 387 | 22 | 0 | 0 | 1991 | 1701 | 1.40 | 1.20 | .93 | .67 | 134 | 164 | 446 | 390 |
|  |  |  | 3935 | 1527 | 65 | 0 | 0 | 4027 | 3575 | 1.40 | 1.10 | 1.07 | .93 | 149 | 160 | 490 | 432 |
|  |  |  | 3075 | 258 | 108 | 0 | 0 | 2588 | 2414 | .97 | 1.33 | .90 | 1.00 | 145 | 158 | 617 | 555 |

STATION B-5 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 MAY | 105 | 2.3 | 2512 | 200 | 237 | 200 | 0 | 2712 | 2260 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3294 | 109 | 455 | 91 | 0 | 3112 | 2637 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1984 | 210 | 127 | 146 | 0 | 1991 | 1613 | -- | -- | -- | -- | -- | -- | -- | -- |
| 3 JUNE | 110 | 3.6 | 3015 | 212 | 98 | 0 | 0 | 3081 | 2685 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2037 | 35 | 130 | 65 | 0 | 1518 | 1315 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2950 | 130 | 81 | 49 | 0 | 2958 | 2587 | -- | -- | -- | -- | -- | -- | -- | -- |
| 1 JULY | 107 | 13.7 | 3225 | 452 | 194 | 65 | 0 | 3730 | 3247 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1634 | 0 | 43 | 0 | 0 | 1692 | 1516 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 731 | 22 | 86 | 0 | 0 | 596 | 490 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 JULY | 97 | 15.5 | 538 | 667 | 22 | 22 | 0 | 1038 | 888 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2215 | 237 | 43 | 108 | 0 | 2150 | 1881 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2107 | 559 | 22 | 22 | 0 | 2584 | 2279 | -- | -- | -- | -- | -- | -- | -- | -- |
| 12 AUG | 104 | 20.3 | 2258 | 538 | 194 | 22 | 0 | 3253 | 2857 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2365 | 108 | 129 | 0 | 0 | 3152 | 2933 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3505 | 129 | 0 | 151 | 0 | 2602 | 2266 | -- | -- | -- | -- | -- | -- | -- | -- |
| 17 SEPT | 104 | 18.1 | 2365 | 452 | 43 | 0 | 0 | 619 | 2511 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2662 | 559 | 215 | 0 | 0 | 3638 | 3057 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4107 | 344 | 215 | 43 | 0 | 4859 | 4324 | -- | -- | -- | -- | -- | -- | -- | -- |
| 15 OCT | 106 | -1.0 | 2107 | 258 | 108 | 0 | 0 | 2436 | 2172 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3161 | 258 | 0 | 22 | 0 | 3489 | 3227 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2602 | 172 | 172 | 22 | 0 | 2160 | 1817 | -- | -- | -- | -- | -- | -- | -- | -- |
| 6 NOV | 102 | 10.8 | 1935 | 688 | 65 | 22 | 0 | 2172 | 1914 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2430 | 344 | 108 | 0 | 0 | 3053 | 2789 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2301 | 473 | 86 | 0 | 0 | 2735 | 2410 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION B-6 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 MAY | 71 | 2.1 | 2494 | 685 | 310 | 1842 | 0 | 4295 | 3198 | 2.10 | 2.27 | .67 | .97 | 168 | 196 | 641 | 584 |
| | | | 2412 | 163 | 81 | 179 | 0 | 2363 | 2049 | 2.33 | 1.83 | 1.27 | .63 | 154 | 184 | 716 | 632 |
| | | | 2233 | 489 | 310 | 147 | 0 | 2363 | 1964 | 2.13 | 2.23 | .90 | .80 | 158 | 173 | 545 | 497 |
| 18 MAY | 80 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.43 | 1.67 | .70 | .70 | 163 | 151 | 753 | 660 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.97 | 2.03 | .93 | .87 | 134 | 168 | 225 | 170 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.80 | 1.73 | .80 | .70 | 149 | 161 | 682 | 602 |
| 3 JUNE | 85 | 3.8 | 3162 | 277 | 277 | 98 | 0 | 2838 | 2438 | 1.80 | 1.63 | .90 | 1.00 | 173 | 167 | 856 | 748 |
| | | | 3472 | 733 | 359 | 147 | 0 | 3247 | 2748 | 1.40 | 1.63 | .47 | .67 | 182 | 172 | 780 | 646 |
| | | | 3456 | 98 | 362 | 293 | 0 | 3544 | 2913 | 1.50 | 2.23 | .53 | .90 | 166 | 182 | 920 | 802 |
| 1 JULY | 84 | 14.5 | 2387 | 65 | 129 | 86 | 0 | 2169 | 1501 | 1.40 | .97 | .63 | .37 | 188 | 183 | 429 | 371 |
| | | | 2838 | 258 | 108 | 125 | 0 | 2819 | 2402 | 1.43 | 1.03 | .73 | .40 | 198 | 244 | 406 | 357 |
| | | | 2322 | 108 | 194 | 43 | 0 | 2337 | 2025 | 1.30 | .77 | .57 | .27 | 223 | 249 | 441 | 376 |
| 13 JULY | 78 | 15.2 | 3204 | 662 | 215 | 301 | 0 | 3558 | 2359 | 3.53 | 1.63 | 2.23 | 1.03 | 162 | 159 | 860 | 805 |
| | | | 2666 | 559 | 108 | 215 | 0 | 2808 | 2356 | 2.53 | 1.33 | 1.57 | .80 | 175 | 169 | 927 | 881 |
| | | | 3182 | 387 | 172 | 323 | 0 | 2713 | 2324 | 2.97 | 1.37 | 1.57 | .43 | 179 | 193 | 896 | 853 |
| 12 AUG | 81 | 19.7 | 3526 | 860 | 258 | 65 | 0 | 4195 | 3816 | 1.70 | 1.53 | .70 | .50 | 195 | 182 | 335 | 304 |
| | | | 3333 | 925 | 237 | 22 | 0 | 3582 | 3047 | 1.80 | 1.57 | .93 | .70 | 181 | 211 | 837 | 794 |
| | | | 4257 | 258 | 129 | 65 | 0 | 4248 | 3932 | 1.53 | 1.47 | .67 | .60 | 192 | 149 | 749 | 708 |
| 17 SEPT | 80 | 18.2 | 3354 | 516 | 258 | 22 | 0 | 3169 | 2842 | 3.17 | 3.10 | 1.17 | 1.37 | 177 | 179 | 396 | 341 |
| | | | 3462 | 1527 | 258 | 22 | 0 | 4889 | 4104 | 2.80 | 2.00 | 1.33 | .47 | 189 | 175 | 447 | 392 |
| | | | 3462 | 516 | 215 | 43 | 0 | 3578 | 3042 | 2.80 | 1.97 | .97 | .70 | 197 | 176 | 422 | 365 |
| 15 OCT | 95 | -1.0 | 3311 | 172 | 323 | 22 | 0 | 2566 | 2230 | 2.50 | 2.17 | 1.23 | 1.20 | 152 | 162 | 353 | 286 |
| | | | 3505 | 1057 | 366 | 0 | 0 | 3365 | 2870 | 2.63 | 1.77 | 1.40 | .67 | 158 | 154 | 462 | 394 |
| | | | 3677 | 516 | 129 | 22 | 0 | 3356 | 3034 | 1.53 | 1.93 | .80 | .83 | 156 | 149 | 324 | 255 |
| 6 NOV | 84 | 10.1 | 3720 | 538 | 86 | 0 | 0 | 3317 | 3083 | 1.50 | 1.57 | 1.17 | 1.30 | 152 | 150 | 769 | 680 |
| | | | 3995 | 366 | 65 | 0 | 0 | 3315 | 3042 | 1.40 | 1.43 | 1.00 | .97 | 150 | 164 | 763 | 696 |
| | | | 4150 | 237 | 129 | 0 | 0 | 3290 | 3047 | 1.23 | 1.37 | .90 | 1.07 | 158 | 160 | 588 | 526 |

STATION B-7 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 MAY | 46 | 2.3 | 3586 | 1630 | 1483 | 277 | 0 | 5081 | 2571 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2624 | 2086 | 1353 | 905 | 0 | 3498 | 2430 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4059 | 2885 | 1206 | 570 | 16 | 4305 | 3069 | -- | -- | -- | -- | | | | |
| 2 JUNE | 44 | 6.0 | 3647 | 3423 | 2689 | 407 | 0 | 5553 | 4202 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3945 | 2967 | 3765 | 212 | 0 | 6077 | 4302 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3341 | 1597 | 4368 | 359 | 0 | 5816 | 4171 | -- | -- | -- | -- | | | | |
| 29 JUNE | 45 | 17.8 | 4257 | 1505 | 1785 | 43 | 0 | 6100 | 5089 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2860 | 2150 | 538 | 43 | 0 | 3842 | 3255 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4773 | 1011 | 2172 | 65 | 0 | 5528 | 4124 | -- | -- | -- | -- | -- | -- | | |
| 13 JULY | 43 | 19.4 | 6966 | 1699 | 2088 | 0 | 0 | 6794 | 5222 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3591 | 3913 | 1763 | 43 | 0 | 5244 | 4270 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5676 | 4408 | 3096 | 86 | 0 | 5349 | 3664 | -- | -- | -- | -- | -- | -- | -- | -- |
| 12 AUG | 43 | 19.4 | 8966 | 3462 | 2043 | 65 | 0 | 10114 | 7267 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4945 | 3419 | 903 | 22 | 0 | 7811 | 6042 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5762 | 1806 | 2537 | 22 | 0 | 7525 | 5872 | -- | -- | -- | -- | -- | -- | -- | -- |
| 17 SEPT | 40 | 15.9 | 3483 | 1570 | 3268 | 129 | 0 | 5594 | 3984 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4171 | 3053 | 3096 | 0 | 0 | 5498 | 3382 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2387 | 3225 | 1398 | 0 | 0 | 3866 | 2617 | -- | -- | -- | -- | -- | -- | -- | -- |
| 15 OCT | 44 | -1.0 | 9202 | 2516 | 1699 | 86 | 22 | 10481 | 7955 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8966 | 4537 | 2537 | 65 | 0 | 9806 | 7686 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9632 | 2129 | 1849 | 86 | 0 | 9628 | 7637 | -- | -- | -- | -- | -- | -- | -- | -- |
| 6 NOV | 44 | 10.7 | 6515 | 3763 | 2137 | 65 | 0 | 7435 | 5590 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6407 | 4300 | 2365 | 237 | 0 | 8069 | 5966 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6694 | 3333 | 1806 | 151 | 0 | 7461 | 5521 | -- | -- | -- | -- | | | | |

STATION B-5 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 MAY | 11 | 7.2 | 2380 | 2380 | 851 | 65 | 49 | 15529 | 2996 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2918 | 896 | 1842 | 49 | 49 | 8251 | 2711 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 594 | 505 | 1076 | 43 | 33 | 5985 | 2279 | -- | -- | -- | -- | | | | |
| 2 JUNE | 11 | 8.0 | 1011 | 13676 | 6944 | 81 | 1418 | 35412 | 10320 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 65 | 7335 | 3635 | 81 | 98 | 27690 | 7787 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5933 | 4010 | 3341 | 65 | 407 | 23102 | 6068 | -- | -- | -- | -- | | | | |
| 29 JUNE | 12 | 17.1 | 3612 | 6042 | 5139 | 86 | 1032 | 25948 | 7779 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2021 | 6106 | 4408 | 0 | 151 | 15570 | 4115 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6170 | 5913 | 4734 | 65 | 344 | 16435 | 5269 | -- | -- | -- | -- | | | | |
| 13 JULY | 13 | 16.8 | 2524 | 28101 | 10170 | 108 | 108 | 105419 | 26187 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6729 | 4644 | 5418 | 129 | 515 | 20926 | 5252 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5504 | 5805 | 5676 | 65 | 258 | 21272 | 4840 | -- | -- | -- | -- | -- | -- | -- | -- |
| 12 AUG | 13 | 17.6 | 7762 | 15437 | 4451 | 172 | 237 | 46111 | 13199 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9740 | 6364 | 8256 | 151 | 172 | 55846 | 17510 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9181 | 13029 | 7375 | 129 | 323 | 75330 | 24564 | -- | -- | -- | -- | -- | -- | -- | -- |
| 17 SEPT | 11 | 16.6 | 6837 | 14233 | 4193 | 0 | 882 | 59916 | 15342 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7568 | 6751 | 3053 | 0 | 280 | 29143 | 8628 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4150 | 1183 | 559 | 0 | 108 | 7344 | 3167 | -- | -- | -- | -- | -- | -- | -- | -- |
| 15 OCT | 11 | -1.0 | 6837 | 8772 | 4279 | 0 | 43 | 37268 | 12218 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7203 | 11933 | 6042 | 0 | 65 | 35552 | 11677 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6192 | 5547 | 5117 | 22 | 538 | 44021 | 11677 | -- | -- | -- | -- | -- | -- | -- | -- |
| 6 NOV | 10 | 10.6 | 3655 | 8127 | 7805 | 22 | 344 | 45083 | 5475 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5504 | 13975 | 4257 | 22 | 280 | 32444 | 5161 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5547 | 13975 | 4322 | 22 | 258 | 28240 | 4876 | -- | -- | -- | -- | | | | |

STATION C-1 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TENE | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 MAY | 20 | 4.0 | 6275 | 342 | 212 | 33 | 0 | 7335 | 5609 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6350 | 98 | 391 | 33 | 0 | 6794 | 5350 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7335 | 1157 | 473 | 49 | 0 | 8264 | 6479 | -- | -- | -- | -- | -- | -- | -- | -- |
| 1 JUNE | 26 | 13.1 | 3993 | 717 | 293 | 163 | 0 | 6189 | 5460 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6390 | 6064 | 3244 | 261 | 0 | 12716 | 9447 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4515 | 5232 | 4010 | 196 | 0 | 15185 | 7275 | -- | -- | -- | -- | -- | -- | -- | -- |
| 28 JUNE | 25 | 15.7 | 5268 | 2430 | 1312 | 172 | 43 | 17826 | 5122 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1650 | 215 | 215 | 86 | 0 | 3029 | 2449 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2150 | 790 | 258 | 172 | 22 | 10387 | 6233 | -- | -- | -- | -- | -- | -- | -- | -- |
| 14 JULY | 26 | 17.5 | 15605 | 1634 | 2580 | 387 | 0 | 8293 | 4721 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 15996 | 1634 | 817 | 344 | 0 | 6063 | 5143 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 22633 | 2580 | 1548 | 430 | 0 | 7155 | 5500 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10 AUG | 26 | 17.2 | 5913 | 22 | 323 | 151 | 22 | 3642 | 2971 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3483 | 86 | 43 | 86 | 0 | 1849 | 1593 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3784 | 43 | 129 | 215 | 22 | 2449 | 2098 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7 SEPT | 21 | 17.8 | 1183 | 151 | 215 | 0 | 0 | 1253 | 866 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1828 | 108 | 237 | 65 | 0 | 3601 | 2150 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1806 | 172 | 516 | 129 | 0 | 3036 | 2156 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10 OCT | 21 | 13.8 | 5289 | 86 | 1183 | 22 | 22 | 7271 | 3924 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8600 | 237 | 3634 | 65 | 172 | 10376 | 5751 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8815 | 22 | 1720 | 0 | 172 | 14682 | 6175 | -- | -- | -- | -- | -- | -- | -- | -- |
| 6 NOV | 24 | 11.7 | 4601 | 86 | 989 | 0 | 65 | 4408 | 2664 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1161 | 258 | 215 | 0 | 22 | 1542 | 860 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2473 | 280 | 22 | 0 | 0 | 1819 | 1567 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C-2 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TENE | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 APR | 45 | 3.4 | 6308 | 5526 | 3276 | 749 | 0 | [illegible] | 11892 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6699 | 5069 | 2918 | 578 | 0 | 15355 | 10455 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8020 | 4580 | 3211 | 1125 | 0 | 16396 | 11857 | -- | -- | -- | -- | -- | -- | -- | -- |
| 1 JUNE | 56 | 7.9 | 277 | 196 | 65 | 0 | 0 | 544 | 409 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5281 | 3977 | 4238 | 375 | 0 | 8655 | 6487 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6662 | 1614 | 4770 | 326 | 0 | 11457 | 7857 | -- | -- | -- | -- | -- | -- | -- | -- |
| 28 JUNE | 53 | 14.9 | 6644 | 3419 | 4193 | 387 | 0 | 9264 | 6777 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3354 | 7547 | 645 | 280 | 0 | 7091 | 5375 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7095 | 2795 | 3483 | 409 | 0 | 11294 | 8675 | -- | -- | -- | -- | -- | -- | -- | -- |
| 14 JULY | 55 | 17.0 | 15007 | 129 | 4386 | 86 | 0 | 5788 | 4279 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 11524 | 86 | 9630 | 516 | 0 | 7198 | 3651 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 13674 | 5375 | 7310 | 602 | 0 | 8359 | 5237 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10 AUG | 47 | 17.1 | 7332 | 13304 | 5483 | 151 | 0 | 17765 | 12135 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8643 | 5031 | 3290 | 237 | 0 | 17587 | 13197 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10299 | 8557 | 4472 | 409 | 0 | 22055 | 16295 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7 SEPT | 47 | 17.8 | 7203 | 11417 | 4257 | 22 | 22 | 12683 | 5021 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7848 | 6085 | 4795 | 0 | 0 | 11087 | 8368 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6735 | 2795 | 4773 | 22 | 0 | 10455 | 7697 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10 OCT | 50 | 14.1 | 4537 | 2494 | 2946 | 0 | 0 | 6934 | 4676 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4687 | 1570 | 3354 | 0 | 0 | 7465 | 5706 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5246 | 1763 | 4257 | 0 | 0 | 9335 | 7157 | -- | -- | -- | -- | -- | -- | -- | -- |
| 6 NOV | 52 | 12.0 | 7826 | 8966 | 3578 | 43 | 43 | 10748 | 7574 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7912 | 2080 | 3935 | 65 | 0 | 8867 | 6237 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7138 | 1247 | 3741 | 22 | 0 | 7424 | 5429 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C-3 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | > 25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | > 25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 APR | 21 | 1.2 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.13 | 3.10 | 1.37 | 1.27 | 177 | 156 | 624 | 449 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.50 | 2.17 | .93 | .87 | 150 | 190 | 123 | 96 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.13 | 2.37 | .77 | .93 | 146 | 155 | 179 | 127 |
| 29 APR | 82 | 2.0 | 5901 | 717 | 1011 | 228 | 0 | 4789 | 3430 | 3.87 | 2.80 | 2.50 | 1.17 | 168 | 163 | 634 | 532 |
| | | | 4955 | 407 | 619 | 342 | 0 | 4518 | 3379 | 2.40 | 2.50 | 1.07 | .83 | 156 | 170 | 805 | 732 |
| | | | 5444 | 375 | 102 | 65 | 0 | 4799 | 3529 | 2.20 | 2.57 | .87 | .73 | 180 | 150 | 760 | 671 |
| 17 MAY | 79 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.37 | 1.90 | 1.27 | .67 | 147 | 178 | 730 | 414 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.97 | 1.93 | .67 | 1.07 | 165 | 172 | 544 | 262 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.27 | 1.93 | 1.17 | 1.00 | 179 | 129 | 336 | 179 |
| 1 JUNE | 81 | 5.2 | 5526 | 424 | 782 | 49 | 0 | 4422 | 3635 | 1.90 | 2.63 | 1.07 | 1.77 | 178 | 191 | 664 | 540 |
| | | | 4727 | 440 | 1222 | 58 | 0 | 3566 | 2766 | 1.57 | 1.93 | .77 | 1.13 | 200 | 198 | 585 | 488 |
| | | | 4939 | 570 | 717 | 310 | 0 | 3677 | 2975 | 1.63 | 1.63 | .80 | .67 | 172 | 188 | 728 | 596 |
| 28 JUNE | 79 | 14.7 | 4408 | 108 | 1097 | 108 | 0 | 3161 | 2356 | 1.43 | 4.53 | .57 | .73 | 179 | 172 | 1083 | 685 |
| | | | 3741 | 688 | 538 | 194 | 0 | 3223 | 2326 | 1.50 | 2.20 | .77 | .70 | 178 | 150 | 1027 | 854 |
| | | | 4193 | 731 | 925 | 154 | 0 | 3625 | 2832 | 1.73 | 1.73 | .90 | .57 | 204 | 175 | 572 | 432 |
| 14 JULY | 79 | 16.7 | 4945 | 43 | 903 | 43 | 0 | 1746 | 1127 | 1.50 | 1.50 | .90 | .77 | 139 | 164 | 715 | 637 |
| | | | 6794 | 1419 | 1806 | 0 | 0 | 2498 | 1350 | 1.33 | 1.33 | .67 | .87 | 160 | 162 | 735 | 624 |
| | | | 8170 | 731 | 1290 | 258 | 43 | 3087 | 2141 | 1.23 | 1.27 | .77 | .87 | 154 | 130 | 454 | 392 |
| 11 AUG | 79 | 16.3 | 3978 | 495 | 624 | 43 | 0 | 3954 | 3199 | 1.13 | 2.87 | .37 | .87 | 162 | 184 | 2085 | 1893 |
| | | | 3763 | 1140 | 602 | 22 | 0 | 4160 | 3292 | 1.73 | 3.00 | .63 | .90 | 196 | 196 | 1347 | 1242 |
| | | | 4580 | 1828 | 731 | 129 | 0 | 5758 | 4481 | .93 | 2.57 | .10 | 1.07 | 208 | 192 | 1703 | 1527 |
| 7 SEPT | 72 | 17.8 | 4236 | 452 | 430 | 43 | 0 | 3178 | 2500 | 1.87 | 3.30 | .83 | .77 | 166 | 157 | 727 | 584 |
| | | | 5504 | 1871 | 731 | 65 | 0 | 4792 | 3803 | 2.40 | 3.27 | 1.10 | .77 | 156 | 154 | 677 | 594 |
| | | | 2752 | 237 | 344 | 0 | 0 | 2621 | 1978 | 2.33 | 3.27 | .83 | .83 | 146 | 155 | 653 | 535 |
| 10 OCT | 79 | 13.6 | 2688 | 344 | 516 | 0 | 0 | 3092 | 2578 | 1.67 | 2.23 | 1.33 | .80 | 164 | 168 | 262 | 233 |
| | | | 3311 | 237 | 473 | 0 | 0 | 3264 | 2352 | 1.73 | 2.40 | .83 | 2.03 | 162 | 162 | 154 | 130 |
| | | | 2021 | 22 | 710 | 0 | 0 | 1883 | 1441 | 1.57 | 2.10 | .63 | .77 | 164 | 167 | 204 | 184 |
| 6 NOV | 79 | 11.6 | 4214 | 172 | 387 | 0 | 0 | 2683 | 2144 | 2.07 | 1.60 | 1.10 | 1.27 | 147 | 158 | 530 | 406 |
| | | | 4236 | 344 | 538 | 0 | 0 | 3373 | 2726 | 2.13 | 2.70 | 1.10 | 2.10 | 143 | 145 | 359 | 318 |
| | | | 3677 | 237 | 817 | 0 | 0 | 3462 | 2814 | 1.97 | 1.93 | .93 | 1.53 | 145 | 136 | 377 | 322 |

STATION C-4 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 MAY | 106 | 2.1 | 2021 | 733 | 456 | 81 | 0 | 2279 | 1703 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1695 | 424 | 391 | 65 | 0 | 1607 | 1193 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1989 | 277 | 505 | 65 | 0 | 2134 | 1682 | -- | -- | -- | -- | -- | -- | -- | -- |
| 1 JUNE | 117 | 3.5 | 3765 | 163 | 277 | 81 | 0 | 2372 | 2024 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4238 | 281 | 359 | 16 | 0 | 2820 | 2367 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3244 | 212 | 98 | 130 | 0 | 2818 | 2448 | -- | -- | -- | -- | -- | -- | -- | -- |
| 25 JUNE | 99 | 12.7 | 2258 | 108 | 323 | 108 | 0 | 2498 | 2055 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2107 | 280 | 581 | 86 | 0 | 2227 | 1748 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1763 | 0 | 404 | 22 | 0 | 1946 | 1511 | -- | -- | -- | -- | -- | -- | -- | -- |
| 14 JULY | 98 | 18.8 | 1720 | 86 | 903 | 258 | 0 | 1075 | 619 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4472 | 43 | 903 | 43 | 0 | 1892 | 1183 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4773 | 3010 | 430 | 86 | 0 | 2467 | 1466 | -- | -- | -- | -- | -- | -- | -- | -- |
| 11 AUG | 113 | 18.3 | 2430 | 301 | 108 | 215 | 0 | 2305 | 1987 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4300 | 774 | 237 | 151 | 0 | 3892 | 3212 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3935 | 151 | 387 | 258 | 0 | 2520 | 2116 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7 SEPT | 93 | 18.6 | 2845 | 538 | 409 | 43 | 0 | 3107 | 2483 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2129 | 215 | 366 | 0 | 0 | 2199 | 1666 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2451 | 172 | 387 | 0 | 0 | 2324 | 1894 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10 OCT | 89 | 14.0 | 1613 | 0 | 559 | 0 | 0 | 1531 | 1292 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1611 | 0 | 753 | 0 | 0 | 619 | 303 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1699 | 43 | 495 | 0 | 0 | 1649 | 1319 | -- | -- | -- | -- | -- | -- | -- | -- |
| 6 NOV | 99 | 10.2 | 2838 | 129 | 430 | 0 | 0 | 2774 | 2354 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3118 | 172 | 452 | 0 | 0 | 3158 | 2711 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2602 | 151 | 258 | 22 | 0 | 2520 | 2193 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C-5 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 16 APR | 160 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.60 | 1.17 | .93 | .50 | 189 | 190 | 194 | 139 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.57 | 1.83 | .43 | 1.17 | 193 | 204 | 402 | 263 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.53 | 1.67 | .83 | .97 | 180 | 207 | 758 | 489 |
| 1 MAY | 156 | 2.1 | 1157 | 244 | 49 | 0 | 0 | 906 | 722 | 2.03 | 2.10 | .60 | .83 | 165 | 176 | 748 | 679 |
| | | | 962 | 424 | 49 | 33 | 0 | 856 | 652 | 2.33 | 1.77 | .83 | .60 | 188 | 168 | 705 | 616 |
| | | | 636 | 668 | 0 | 65 | 0 | 839 | 645 | 1.73 | 2.17 | .60 | .80 | 165 | 184 | 947 | 880 |
| 17 MAY | 155 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.53 | 1.30 | .63 | .77 | 138 | 148 | 623 | 304 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.27 | 1.40 | .60 | .87 | 170 | 142 | 831 | 780 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.00 | 1.23 | .20 | .57 | 151 | 134 | 1005 | 935 |
| 1 JUNE | 158 | 3.3 | 2722 | 326 | 0 | 81 | 0 | 1873 | 1625 | 1.47 | 1.60 | .93 | .57 | 172 | 184 | 1503 | 1167 |
| | | | 2119 | 1418 | 33 | 0 | 0 | 2010 | 1703 | 1.60 | 1.63 | .93 | .83 | 176 | 179 | 1382 | 1098 |
| | | | 3276 | 1027 | 33 | 16 | 0 | 2720 | 2289 | 1.37 | 1.40 | .40 | -1.00 | 170 | 173 | 1123 | 922 |
| 29 JUNE | 158 | 8.8 | 2817 | 344 | 43 | 43 | 0 | 2307 | 1582 | 1.33 | 1.37 | .53 | -1.00 | 159 | 162 | 511 | 462 |
| | | | 3053 | 301 | 22 | 65 | 0 | 2227 | 1929 | 1.33 | 1.07 | .70 | .57 | 154 | 163 | 691 | 587 |
| | | | 2064 | 0 | 86 | 22 | 0 | 1402 | 1105 | 1.23 | .90 | .80 | .33 | 177 | 162 | 722 | 605 |
| 14 JULY | 157 | 16.4 | 2193 | 129 | 129 | 0 | 0 | 903 | 675 | 1.13 | .83 | .60 | .43 | 143 | 147 | 707 | 645 |
| | | | 4859 | 129 | 86 | 43 | 0 | 1376 | 1109 | 1.13 | 1.10 | .60 | .43 | 143 | 146 | 978 | 962 |
| | | | 1376 | 129 | 172 | 0 | 0 | 546 | 400 | 1.73 | 1.20 | .87 | .60 | 154 | 151 | 781 | 739 |
| 11 AUG | 165 | 19.2 | 3204 | 258 | 0 | 129 | 0 | 3034 | 2586 | 1.40 | 1.13 | .57 | .50 | 194 | 193 | 1981 | 1877 |
| | | | 3655 | 753 | 108 | 0 | 0 | 3285 | 2842 | 1.53 | .80 | .63 | .33 | 190 | 178 | 1422 | 1347 |
| | | | 3354 | 1742 | 129 | 22 | 0 | 3887 | 3324 | 1.67 | .80 | .73 | .40 | 204 | 206 | 1537 | 1416 |
| 7 SEPT | 149 | 19.0 | 2688 | 925 | 0 | 0 | 0 | 3558 | 3025 | 2.70 | 1.13 | 1.07 | .77 | 160 | 184 | 392 | 354 |
| | | | 2344 | 946 | 65 | 0 | 0 | 2857 | 2288 | 2.57 | 1.13 | 1.80 | -1.00 | 166 | 175 | 513 | 459 |
| | | | 2623 | 602 | 151 | 0 | 0 | 2926 | 2430 | 2.77 | 1.23 | 1.23 | 1.00 | 168 | 179 | 531 | 482 |
| 10 OCT | 149 | 13.1 | 1527 | 65 | 86 | 0 | 0 | 1210 | 1023 | 1.83 | 2.03 | .97 | 1.10 | 146 | 162 | 309 | 267 |
| | | | 2129 | 108 | 43 | 0 | 0 | 1582 | 1408 | 1.80 | 1.97 | 1.30 | 1.20 | 144 | 153 | 499 | 454 |
| | | | 1695 | 237 | 22 | 0 | 0 | 1346 | 1189 | 1.60 | 1.73 | 1.10 | 1.47 | 155 | 155 | 442 | 409 |
| 6 NOV | 155 | 10.7 | 2193 | 237 | 86 | 0 | 0 | 2023 | 1772 | 2.73 | 4.33 | 1.53 | 2.33 | 142 | 166 | 851 | 737 |
| | | | 1871 | 86 | 0 | 0 | 0 | 1729 | 1561 | 2.47 | 3.13 | .83 | 1.60 | 162 | 162 | 1294 | 1173 |
| | | | 2365 | 86 | 0 | 0 | 0 | 1877 | 1754 | 2.20 | 2.37 | .87 | .63 | 140 | 162 | 1189 | 1107 |

STATION C-6 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE. ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 1 MAY | 86 | 2.0 | 1842 | 505 | 179 | 179 | 0 | 2667 | 2334 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1255 | 33 | 212 | 58 | 0 | 1756 | 1503 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1353 | 733 | 310 | 179 | 0 | 2015 | 1571 | -- | -- | -- | -- | -- | -- | -- | -- |
| 1 JUNE | 53 | 4.8 | 2673 | 228 | 473 | 147 | 0 | 2958 | 2559 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2461 | 619 | 554 | 375 | 0 | 3361 | 2910 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3130 | 1043 | 668 | 375 | 0 | 5193 | 3519 | -- | -- | -- | -- | -- | -- | -- | -- |
| 29 JUNE | 99 | 15.7 | 2193 | 194 | 258 | 22 | 0 | 2215 | 1785 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2365 | 86 | 172 | 0 | 0 | 2425 | 2066 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3440 | 688 | 215 | 65 | 0 | 4444 | 3754 | -- | -- | -- | -- | -- | -- | -- | -- |
| 14 JULY | 98 | 19.0 | 6278 | 258 | 344 | 129 | 0 | 3186 | 2455 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6708 | 1075 | 387 | 129 | 0 | 3801 | 2795 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3612 | 559 | 129 | 129 | 0 | 2339 | 1797 | -- | -- | -- | -- | -- | -- | -- | -- |
| 11 AUG | 95 | 18.8 | 3784 | 774 | 237 | 65 | 0 | 4208 | 3612 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3956 | 473 | 215 | 43 | 0 | 4992 | 4388 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3290 | 237 | 129 | 129 | 0 | 3651 | 3219 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7 SEPT | 82 | 20.0 | 5762 | 1097 | 129 | 22 | 0 | 4693 | 3225 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6730 | 753 | 237 | 86 | 0 | 6461 | 5622 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5268 | 473 | 172 | 0 | 0 | 4842 | 4038 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10 OCT | 98 | 13.5 | 3311 | 43 | 215 | 43 | 22 | 2875 | 2591 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2387 | 65 | 129 | 0 | 0 | 1969 | 1716 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1548 | 65 | 151 | 0 | 0 | 1434 | 1249 | -- | -- | -- | -- | -- | -- | -- | -- |
| 6 NOV | 53 | 9.1 | 3526 | 323 | 237 | 0 | 0 | 3618 | 3247 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3698 | 559 | 280 | 0 | 0 | 4259 | 3786 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4150 | 796 | 301 | 0 | 0 | 4739 | 4096 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C-7 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 APR | 55 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.63 | 3.13 | 1.83 | 1.13 | 221 | -1 | 510 | 466 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.17 | 2.27 | .90 | .90 | -1 | 191 | 403 | 365 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.10 | 2.17 | 1.17 | 1.00 | 200 | 169 | 412 | 378 |
| 2 MAY | 55 | 1.9 | 3260 | 717 | 440 | 424 | 0 | 3844 | 3108 | 2.40 | 2.53 | .70 | .90 | 196 | 177 | 339 | 287 |
| | | | 4482 | 1125 | 668 | 310 | 0 | 5037 | 4321 | 2.93 | 2.80 | .77 | 1.17 | 174 | 168 | 321 | 278 |
| | | | 4580 | 782 | 424 | 277 | 0 | 4636 | 4160 | 2.53 | 2.43 | .73 | .80 | 160 | 179 | 327 | 289 |
| 16 MAY | 54 | -1.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.50 | 3.50 | 1.60 | 1.13 | 137 | 146 | 156 | 124 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.50 | 2.67 | 1.20 | 1.17 | 154 | 160 | 465 | 400 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.17 | 2.37 | 1.50 | 1.03 | 154 | 146 | 477 | 298 |
| 2 JUNE | 52 | 6.9 | 4906 | 733 | 2526 | 163 | 0 | 6183 | 4916 | 2.17 | 2.60 | 1.00 | .97 | 177 | 186 | 531 | 292 |
| | | | 5200 | 929 | 2396 | 212 | 0 | 6272 | 5040 | 2.33 | 2.50 | 1.03 | .90 | 185 | 171 | 573 | 338 |
| | | | 5249 | 929 | 1239 | 261 | 0 | 5438 | 4427 | 2.27 | 2.20 | 1.10 | .60 | 161 | 196 | 545 | 297 |
| 29 JUNE | 59 | 16.2 | 3935 | 559 | 473 | 151 | 0 | 5444 | 4745 | 1.83 | 2.17 | 1.10 | .83 | 202 | 210 | 252 | 191 |
| | | | 3569 | 1054 | 903 | 0 | 0 | 5465 | 4414 | 2.10 | 2.90 | 1.17 | .70 | 204 | 210 | 92 | 65 |
| | | | 3763 | 1333 | 624 | 43 | 0 | 5132 | 4423 | 2.37 | 2.07 | 1.10 | .60 | 225 | 211 | 134 | 114 |
| 14 JULY | 53 | 20.9 | 9245 | 1849 | 1591 | 129 | 43 | 7469 | 5177 | 2.13 | 2.00 | 1.20 | 1.07 | 169 | 136 | 478 | 394 |
| | | | 7998 | 1806 | 1462 | 172 | 43 | 7263 | 5672 | 2.30 | 1.77 | 1.37 | .80 | 139 | 178 | 474 | 421 |
| | | | 9585 | 946 | 1462 | 172 | 0 | 6029 | 4644 | 2.17 | 1.67 | 1.17 | .77 | 178 | 127 | 287 | 225 |
| 11 AUG | 50 | 19.3 | 4945 | 1527 | 495 | 0 | 0 | 7295 | 6452 | 2.07 | 3.27 | .73 | 1.20 | 186 | 198 | 263 | 228 |
| | | | 5590 | 1484 | 688 | 43 | 0 | 8045 | 6985 | 1.97 | 3.13 | 1.00 | 1.13 | 184 | 191 | 583 | 526 |
| | | | 6085 | 409 | 882 | 86 | 0 | 7011 | 6022 | 2.37 | 3.33 | 1.23 | 1.20 | 187 | 193 | 834 | 741 |
| 7 SEPT | 49 | 18.0 | 4644 | 1269 | 1613 | 0 | 0 | 8278 | 6691 | 2.07 | 1.83 | 1.03 | .67 | 150 | 155 | 155 | 82 |
| | | | 6128 | 882 | 1462 | 0 | 0 | 8869 | 7585 | 2.20 | 2.03 | 1.23 | .67 | 149 | 151 | 64 | 28 |
| | | | 5225 | 989 | 710 * | 0 | 0 | 9013 | 7633 | 2.03 | 2.27 | .97 | .97 | 123 | 148 | 193 | 31 |
| 10 OCT | 53 | 11.7 | 3182 | 43 | 495 | 0 | 0 | 4526 | 3909 | 2.70 | 1.67 | 1.93 | 1.43 | 160 | 174 | 416 | 339 |
| | | | 5203 | 86 | 903 | 0 | 0 | 7076 | 6269 | 1.97 | 1.67 | 1.07 | .97 | 156 | 153 | 76 | 62 |
| | | | 3999 | 194 | 538 | 0 | 0 | 5698 | 4857 | 1.77 | 1.47 | .83 | .97 | 167 | 155 | 90 | 72 |
| 6 NOV | 52 | 5.8 | 5999 | 753 | 1226 | 0 | 0 | 5586 | 4313 | 2.00 | 3.10 | .40 | 1.40 | 164 | 162 | 527 | 440 |
| | | | 3870 | 753 | 43 | 0 | 0 | 6508 | 5902 | 2.03 | 2.20 | .93 | .77 | 156 | 163 | 196 | 139 |
| | | | 6106 | 645 | 409 | 0 | 0 | 6747 | 5904 | 2.03 | 1.83 | .80 | .80 | 152 | 150 | 549 | 451 |

STATION C9-1 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 MAY | 39 | 6.3 | 8003 | 1557 | 342 | 665 | 0 | 11679 | 10098 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7840 | 2315 | 1206 | 522 | 0 | 11884 | 9772 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8215 | 1989 | 717 | 293 | 98 | 12528 | 10809 | -- | -- | -- | -- | -- | -- | -- | -- |
| 25 JUNE | 37 | 13.0 | 5805 | 1161 | 1462 | 108 | 0 | 7562 | 6029 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2752 | 2623 | 366 | 129 | 0 | 5212 | 4152 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3161 | 1935 | 172 | 65 | 0 | 5222 | 4392 | -- | -- | -- | -- | -- | -- | -- | -- |
| 20 JULY | 39 | 17.7 | 8106 | 344 | 882 | 129 | 0 | 9228 | 7798 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6988 | 2215 | 1333 | 129 | 0 | 10367 | 8566 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9052 | 1312 | 1806 | 151 | 0 | 11767 | 9499 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10 AUG | 39 | 15.2 | 7633 | 4859 | 473 | 65 | 0 | 11952 | 9875 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8901 | 4386 | 2903 | 0 | 0 | 14173 | 11223 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6859 | 2795 | 301 | 108 | 0 | 12150 | 9621 | -- | -- | -- | -- | -- | -- | -- | -- |
| 20 SEPT | 38 | 16.5 | 9116 | 2860 | 2023 | 86 | 0 | 13807 | 11210 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8342 | 4021 | 1634 | 0 | 0 | 10840 | 8475 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 13459 | 1720 | 5010 | 43 | 0 | 17593 | 13382 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 OCT | 39 | 14.0 | 7396 | 2838 | 2602 | 43 | 0 | 10748 | 9067 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10879 | 1333 | 2064 | 22 | 0 | 11487 | 5787 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8772 | 2774 | 753 | 22 | 0 | 9660 | 8658 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 NOV | 38 | 11.4 | 11890 | 3075 | 4519 | 602 | 0 | 11945 | 7725 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 11266 | 4386 | 1578 | 86 | 0 | 11859 | 8845 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9568 | 4236 | 1355 | 215 | 0 | 11030 | 8849 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C4-2 1965

| | | SFC | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN $MG/M^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK $MG/M^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DPTH | TEM | | | | | | | ASH | DRY | | ASH FREE | | | | | ASH |
| DATE | METR | C | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | FREE |
| 28 MAY | 98 | 3.8 | 4352 | 1337 | 570 | 407 | 0 | 5007 | 4155 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5949 | 1141 | 196 | 485 | 0 | 6409 | 5399 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5786 | 1467 | 310 | 342 | 81 | 5581 | 4659 | -- | -- | -- | -- | -- | -- | -- | -- |
| 25 JUNE | 96 | 13.1 | 5805 | 1677 | 538 | 43 | 0 | 6575 | 5532 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5612 | 1333 | 194 | 237 | 0 | 6149 | 5308 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6450 | 1806 | 425 | 129 | 0 | 6368 | 5295 | -- | -- | -- | -- | -- | -- | -- | -- |
| 20 JULY | 97 | 16.0 | 2860 | 129 | 237 | 43 | 0 | 2249 | 1817 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 925 | 581 | 43 | 22 | 0 | 1090 | 817 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 258 | 258 | 22 | 22 | 0 | 318 | 262 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9 AUG | 96 | 12.2 | 8622 | 1505 | 516 | 22 | 0 | 7789 | 6244 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4021 | 2279 | 301 | 86 | 0 | 5207 | 3892 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4988 | 1355 | 323 | 237 | 0 | 5171 | 4511 | -- | -- | -- | -- | -- | -- | -- | -- |
| 20 SEPT | 92 | 17.9 | 5612 | 1505 | 344 | 0 | 0 | 5820 | 4857 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4021 | 581 | 323 | 22 | 0 | 3386 | 2961 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5741 | 1806 | 516 | 0 | 0 | 5665 | 4743 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 OCT | 94 | 14.3 | 4601 | 968 | 430 | 0 | 0 | 4107 | 3608 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5203 | 1914 | 344 | 0 | 0 | 5964 | 5263 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4580 | 688 | 237 | 0 | 0 | 4220 | 3687 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 NOV | 95 | 11.0 | 4773 | 2043 | 430 | 0 | 0 | 5704 | 4487 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4730 | 344 | 409 | 0 | 0 | 3199 | 2681 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2430 | 903 | 129 | 0 | 0 | 2939 | 2283 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION D-1 1965

| | | SFC | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN $MG/M^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK $MG/M^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DPTH | TEM | | | | | | | ASH | DRY | | ASH FREE | | | | | ASH |
| DATE | METR | C | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | FREE |
| 27 MAY | 36 | 6.5 | 5118 | 570 | 2771 | 0 | 0 | 7487 | 5276 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5868 | 1874 | 6867 | 33 | 0 | 12119 | 6706 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7107 | 1337 | 7987 | 81 | 0 | 11927 | 6377 | -- | -- | -- | -- | -- | -- | -- | -- |
| 23 JUNE | 32 | 7.5 | 8665 | 1591 | 1204 | 43 | 22 | 6878 | 5741 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4687 | 839 | 753 | 0 | 0 | 6695 | 5388 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4193 | 774 | 1785 | 43 | 0 | 6940 | 4906 | -- | -- | -- | -- | -- | -- | -- | -- |
| 16 JULY | 32 | 14.2 | 4300 | 1398 | 3913 | 0 | 0 | 7413 | 5422 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5203 | 1484 | 731 | 86 | 151 | 7091 | 5824 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8622 | 1849 | 4773 | 22 | 0 | 9585 | 6459 | -- | -- | -- | -- | -- | -- | -- | -- |
| 12 AUG | 32 | 16.0 | 7461 | 753 | 1505 | 43 | 0 | 7703 | 6433 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4773 | 1634 | 989 | 22 | 0 | 8774 | 5958 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8966 | 796 | 1161 | 22 | 0 | 8151 | 6852 | -- | -- | -- | -- | -- | -- | -- | -- |
| 17 SEPT | 30 | 14.1 | 6644 | 1032 | 2516 | 0 | 0 | 7839 | 5612 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7074 | 2731 | 2129 | 0 | 22 | 8520 | 6063 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6644 | 1226 | 731 | 22 | 0 | 7832 | 6216 | -- | -- | -- | -- | -- | -- | -- | -- |
| 14 OCT | 30 | 11.1 | 6450 | 1333 | 2604 | 0 | 0 | 7454 | 5278 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7504 | 1247 | 1161 | 0 | 0 | 9133 | 6459 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6085 | 559 | 1398 | 43 | 0 | 5680 | 4259 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9 NOV | 30 | 9.0 | 7052 | 1720 | 2000 | 65 | 0 | 7557 | 4962 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6880 | 2107 | 1204 | 22 | 0 | 6420 | 4934 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6773 | 301 | 667 | 65 | 0 | 6115 | 5106 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION D-2 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | DRY | | ASH FREE | | | | | |
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 27 APR | 82 | 1.6 | 1956 | 456 | 0 | 212 | 16 | 2003 | 1667 | 2.87 | 2.57 | .97 | 1.03 | 174 | 146 | 981 | 824 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.97 | 2.53 | .83 | .57 | 164 | 179 | 717 | 654 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.00 | 2.63 | .77 | .90 | 158 | 202 | 979 | 913 |
| 10 MAY | 97 | 2.2 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.77 | 2.37 | .77 | .73 | 149 | 190 | 747 | 690 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.70 | 2.87 | .70 | .83 | 176 | 166 | 296 | 237 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.67 | 2.13 | .97 | .77 | 174 | 205 | 612 | 565 |
| 27 MAY | 126 | 3.0 | 5232 | 114 | 293 | 65 | 0 | 4026 | 3327 | 2.13 | 2.43 | 1.23 | 1.40 | 180 | 181 | 1207 | 1044 |
| | | | 4091 | 473 | 228 | 33 | 16 | 3943 | 3330 | 1.37 | 2.57 | 1.00 | 1.03 | 179 | 152 | 1153 | 1030 |
| | | | 2820 | 326 | 228 | 65 | 0 | 2694 | 2254 | 1.90 | 3.13 | .83 | 1.07 | 146 | 170 | 961 | 874 |
| 23 JUNE | 107 | 5.8 | 1118 | 796 | 129 | 43 | 0 | 1780 | 946 | 1.80 | 1.60 | .90 | .93 | 196 | 206 | 832 | 757 |
| | | | 4322 | 1226 | 301 | 108 | 0 | 4150 | 3416 | 1.53 | 1.43 | .73 | .67 | 210 | 206 | 1044 | 918 |
| | | | 3569 | 753 | 108 | 86 | 0 | 3412 | 2894 | 1.47 | 1.70 | .83 | 1.10 | 194 | 200 | 887 | 798 |
| 16 JULY | 105 | 14.5 | 3139 | 280 | 258 | 0 | 0 | 1948 | 1529 | 1.93 | 1.17 | 1.10 | .57 | 198 | 186 | 661 | 591 |
| | | | 2860 | 280 | 172 | 22 | 0 | 1529 | 1314 | 2.03 | 1.70 | 1.27 | 1.33 | 208 | 172 | 1170 | 1076 |
| | | | 538 | 215 | 0 | 0 | 0 | 355 | 327 | 2.17 | 1.00 | 1.27 | .63 | 176 | 194 | 874 | 790 |
| 12 AUG | 106 | 17.3 | 4214 | 839 | 129 | 22 | 0 | 3229 | 2765 | 1.27 | .97 | .73 | .47 | 185 | 145 | 320 | 291 |
| | | | 3978 | 22 | 495 | 22 | 0 | 2324 | 1871 | 1.60 | 1.27 | .70 | .43 | 184 | 190 | 235 | 213 |
| | | | 3591 | 538 | 129 | 0 | 0 | 2853 | 2191 | 1.33 | 1.00 | .57 | .43 | 199 | 188 | 254 | 227 |
| 17 SEPT | 102 | 14.9 | 3440 | 172 | 538 | 0 | 0 | 2324 | 1929 | 2.80 | 2.10 | 1.40 | 1.00 | 151 | 145 | 818 | 721 |
| | | | 4795 | 258 | 581 | 43 | 0 | 3879 | 3287 | 2.60 | 1.90 | 1.40 | .90 | 156 | 155 | 712 | 660 |
| | | | 3053 | 237 | 473 | 22 | 0 | 2649 | 2247 | 2.67 | 1.97 | 1.03 | 1.00 | 146 | 146 | 682 | 629 |
| 14 OCT | 100 | 11.6 | 4816 | 387 | 344 | 0 | 0 | 4128 | 3565 | 1.73 | 1.70 | .77 | .67 | 152 | 165 | 475 | 442 |
| | | | 3354 | 65 | 387 | 0 | 0 | 2651 | 2247 | 1.63 | 1.77 | .63 | .77 | 155 | 150 | 508 | 473 |
| | | | 5182 | 473 | 194 | 22 | 0 | 4392 | 3810 | 1.57 | 1.63 | .80 | .63 | 141 | 152 | 92 | 73 |
| 9 NOV | 94 | 10.0 | 1097 | 430 | 65 | 0 | 0 | 1466 | 1221 | 1.97 | 1.50 | 1.60 | 1.13 | 155 | 159 | 1234 | 1095 |
| | | | 4193 | 516 | 538 | 0 | 0 | 4569 | 3911 | 1.83 | 1.23 | 1.33 | 1.10 | 148 | 170 | 1161 | 1063 |
| | | | 4924 | 409 | 473 | 22 | 0 | 4810 | 4068 | 1.63 | 1.50 | 1.10 | 1.27 | 163 | 174 | 1024 | 922 |

STATION D-3 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | DRY | | ASH FREE | | | | | |
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 27 APR | 174 | 1.0 | 1874 | 578 | 49 | 130 | 0 | 1824 | 1480 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2200 | 505 | 33 | 16 | 0 | 1690 | 1407 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1777 | 831 | 65 | 147 | 0 | 1493 | 1190 | -- | -- | -- | -- | -- | -- | -- | -- |
| 27 MAY | 168 | 2.8 | 2152 | 326 | 0 | 65 | 0 | 1786 | 1488 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2168 | 440 | 0 | 16 | 33 | 1830 | 1570 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2689 | 244 | 33 | 16 | 114 | 2158 | 1826 | -- | -- | -- | -- | -- | -- | -- | -- |
| 24 JUNE | 172 | 7.0 | 151 | 0 | 0 | 0 | 0 | 185 | 1350 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1505 | 473 | 43 | 0 | 0 | 1539 | 159 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1613 | 258 | 43 | 0 | 0 | 1724 | 1464 | -- | -- | -- | -- | -- | -- | -- | -- |
| 16 JULY | 172 | 16.0 | 710 | 0 | 0 | 0 | 0 | 615 | 561 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |
| 12 AUG | 165 | 17.9 | 1763 | 172 | 108 | 22 | 0 | 2417 | 2159 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1097 | 495 | 22 | 0 | 0 | 2027 | 1509 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1656 | 452 | 22 | 22 | 0 | 2051 | 1795 | -- | -- | -- | -- | -- | -- | -- | -- |
| 20 SEPT | 174 | 14.7 | 1785 | 430 | 65 | 0 | 0 | 2077 | 1840 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1634 | 258 | 65 | 0 | 0 | 1978 | 1742 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1247 | 4085 | 22 | 22 | 0 | 2531 | 2193 | -- | -- | -- | -- | -- | -- | -- | -- |
| 14 OCT | 171 | 10.8 | 1914 | 280 | 86 | 0 | 0 | 2363 | 2073 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1419 | 360 | 22 | 22 | 0 | 1750 | 1572 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2043 | 774 | 65 | 0 | 0 | 2694 | 2365 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9 NOV | 172 | 7.9 | 1355 | 194 | 43 | 0 | 0 | 1699 | 1456 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1484 | 366 | 43 | 0 | 0 | 1696 | 1438 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1871 | 22 | 129 | 0 | 0 | 2111 | 1845 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION E-4 1965

| | | | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | DRY | | ASH FREE | | | | | |
| DATE | DPTH METR | SFC TEM C | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 27 APR | 141 | 1.7 | 1826 | 326 | 98 | 33 | 0 | 1521 | 1198 | 1.43 | 1.33 | 1.17 | .73 | 168 | 189 | 464 | 410 |
| | | | 1483 | 880 | 0 | 33 | 0 | 1322 | 1118 | 1.40 | 1.07 | .73 | .90 | 172 | 176 | 737 | 679 |
| | | | 2624 | 913 | 49 | 49 | 0 | 1923 | 1640 | 1.33 | 1.07 | .80 | .57 | 170 | 156 | 580 | 519 |
| 10 MAY | 137 | 2.3 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.40 | 1.30 | .67 | .53 | 168 | 143 | 398 | 368 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.27 | 1.20 | .63 | .40 | 168 | 177 | 414 | 383 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.30 | 1.30 | .40 | .60 | 155 | 164 | 537 | 479 |
| 27 MAY | 125 | 2.8 | 3521 | 81 | 98 | 16 | 0 | 1881 | 1576 | 1.67 | 2.20 | 1.03 | 1.43 | 132 | 190 | 1256 | 1072 |
| | | | 3244 | 1027 | 196 | 16 | 163 | 2623 | 2218 | 1.43 | 1.63 | .70 | 1.00 | 177 | 143 | 1288 | 1053 |
| | | | 2331 | 456 | 0 | 65 | 0 | 1632 | 1423 | 1.50 | 2.43 | .90 | 1.73 | 150 | 158 | 1283 | 1110 |
| 24 JUNE | 136 | 8.5 | 1226 | 409 | 0 | 0 | 0 | 1954 | 1763 | 2.00 | .80 | 1.23 | .40 | 186 | 180 | 538 | 477 |
| | | | 2406 | 0 | 108 | 22 | 0 | 2294 | 1589 | 1.43 | 1.53 | .93 | 1.03 | 184 | 178 | 674 | 579 |
| | | | 215 | 258 | 0 | 22 | 0 | 288 | 258 | 1.60 | 1.37 | .80 | .73 | 182 | 167 | 461 | 403 |
| 16 JULY | 132 | 15.5 | 2365 | 624 | 108 | 65 | 0 | 2040 | 1694 | 1.33 | 1.20 | .70 | .73 | 159 | 169 | 407 | 371 |
| | | | 667 | 194 | 22 | 0 | 0 | 686 | 2561 | 1.40 | 1.00 | -1.00 | .67 | 150 | 160 | 948 | 912 |
| | | | 3118 | 925 | 22 | 0 | 0 | 2593 | 944 | 1.33 | 1.17 | 1.13 | .70 | 154 | 152 | 933 | 857 |
| 12 AUG | 128 | 17.7 | 3440 | 538 | 65 | 22 | 0 | 2634 | 2303 | 1.53 | .93 | .97 | .63 | 192 | 177 | 245 | 206 |
| | | | 2924 | 1054 | 65 | 22 | 0 | 2614 | 2230 | 1.43 | .73 | .73 | .30 | 192 | 193 | 206 | 178 |
| | | | 2838 | 0 | 22 | 0 | 0 | 2043 | 1804 | 1.20 | 1.00 | .63 | .53 | 198 | 185 | 249 | 224 |
| 20 SEPT | 131 | 15.0 | 2623 | 710 | 151 | 0 | 0 | 2212 | 1716 | 2.13 | 1.77 | 1.47 | 1.07 | 154 | 169 | 1244 | 1159 |
| | | | 2795 | 0 | 43 | 0 | 0 | 2068 | 1877 | 2.53 | 1.30 | .97 | .53 | 125 | 181 | 878 | 816 |
| | | | 2408 | 108 | 22 | 0 | 0 | 1815 | 1647 | 2.10 | 1.30 | 1.13 | .77 | 167 | 167 | 1259 | 1173 |
| 13 OCT | 128 | 11.9 | 1312 | 22 | 0 | 0 | 0 | 578 | 507 | 1.40 | 1.13 | .63 | .77 | 153 | 168 | 505 | 467 |
| | | | 1570 | 22 | 22 | 0 | 0 | 1135 | 983 | 1.27 | 1.13 | .53 | .50 | 160 | 173 | 348 | 312 |
| | | | 2731 | 22 | 86 | 0 | 0 | 1821 | 1610 | 1.47 | 1.23 | .80 | .43 | 160 | 163 | 266 | 238 |
| 7 NOV | 129 | 7.9 | 2752 | 495 | 108 | 0 | 0 | 2513 | 2178 | 1.70 | 1.27 | 1.37 | 1.03 | 161 | 141 | 760 | 708 |
| | | | 3053 | 151 | 43 | 22 | 0 | 2322 | 2090 | 1.37 | 1.53 | 1.23 | 1.33 | 150 | 168 | 1069 | 984 |
| | | | 3311 | 172 | 0 | 0 | 0 | 2838 | 2535 | 1.40 | 1.53 | .60 | .93 | 161 | 160 | 783 | 688 |

STATION E-5 1965

| | | | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | DRY | | ASH FREE | | | | | |
| DATE | DPTH METR | SFC TEM C | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 23 APR | 117 | 1.5 | 2249 | 782 | 147 | 58 | 0 | 1904 | 1531 | 1.73 | 1.53 | .90 | 1.23 | 158 | 154 | 403 | 298 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.63 | 1.30 | .63 | .83 | 165 | 176 | 1293 | 1199 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.63 | 1.87 | .97 | .67 | 166 | 167 | 961 | 867 |
| 10 MAY | 121 | 2.2 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.53 | 1.30 | .77 | .67 | 183 | 179 | 1066 | 1002 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.00 | 1.23 | -1.00 | .53 | 192 | 152 | 899 | 841 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.57 | 1.13 | .83 | .53 | 197 | 140 | 506 | 468 |
| 26 MAY | 128 | 2.5 | 1532 | 342 | 0 | 0 | 0 | 797 | 667 | 1.70 | 2.07 | 1.10 | 1.07 | 157 | 183 | 823 | 719 |
| | | | 2331 | 147 | 0 | 33 | 0 | 1632 | 2318 | 2.00 | 1.67 | 1.93 | .90 | 150 | 147 | 791 | 710 |
| | | | 2494 | 603 | 212 | 49 | 0 | 2769 | 1389 | 1.63 | 1.50 | 1.10 | .90 | 165 | 128 | 922 | 822 |
| 24 JUNE | 131 | 13.5 | 3247 | 602 | 0 | 0 | 0 | 2174 | 1845 | 1.37 | 1.57 | .77 | .87 | 173 | 182 | 705 | 583 |
| | | | 624 | 731 | 0 | 22 | 0 | 748 | 645 | 1.37 | 1.50 | .73 | .80 | 176 | 188 | 732 | 639 |
| | | | 3827 | 1333 | 0 | 108 | 0 | 3709 | 2976 | 1.57 | 1.53 | 1.07 | 1.00 | 173 | 172 | 596 | 527 |
| 15 JULY | 127 | 17.0 | 4171 | 452 | 151 | 0 | 0 | 2950 | 2524 | 1.47 | 1.00 | .80 | .73 | 201 | 184 | 809 | 765 |
| | | | 3513 | 1570 | 323 | 0 | 0 | 3668 | 3004 | 1.43 | .90 | .77 | .50 | 204 | 201 | 996 | 921 |
| | | | 4042 | 710 | 258 | 0 | 0 | 3309 | 2868 | 1.20 | 1.03 | .70 | .73 | 219 | 179 | 291 | 255 |
| 11 AUG | 128 | 19.4 | 2580 | 172 | 0 | 22 | 0 | 2457 | 2180 | 1.30 | 1.50 | .80 | .83 | 186 | 202 | 129 | 104 |
| | | | 4150 | 194 | 43 | 65 | 0 | 3780 | 3315 | 1.43 | 1.77 | .90 | 1.10 | 182 | 191 | 173 | 153 |
| | | | 3483 | 280 | 65 | 86 | 0 | 3236 | 2838 | 1.53 | 1.30 | .90 | .63 | 188 | 209 | 219 | 179 |
| 13 SEPT | 125 | 18.2 | 4042 | 108 | 43 | 0 | 0 | 3434 | 3029 | 2.10 | 1.57 | 1.07 | .73 | 163 | 172 | 161 | 109 |
| | | | 4214 | 237 | 43 | 0 | 0 | 2909 | 2559 | 2.20 | 2.00 | 1.07 | .97 | 172 | 178 | 111 | 70 |
| | | | 4795 | 43 | 108 | 0 | 0 | 2741 | 2417 | 1.93 | 1.83 | .97 | .87 | 158 | 181 | 178 | 119 |
| 6 OCT | 125 | 12.1 | 4150 | 0 | 194 | 0 | 0 | 2851 | 2477 | 1.37 | 1.33 | .73 | .57 | 155 | 166 | 400 | 368 |
| | | | 2989 | 129 | 237 | 0 | 0 | 2795 | 2427 | 1.47 | 1.57 | .70 | .70 | 163 | 173 | 166 | 145 |
| | | | 3505 | 258 | 323 | 65 | 0 | 3530 | 3165 | 1.40 | 1.20 | .73 | .53 | 196 | 179 | 313 | 282 |
| 7 NOV | 121 | 7.9 | 4644 | 430 | 65 | 22 | 0 | 3457 | 3107 | 1.67 | 1.40 | 1.37 | 1.20 | 139 | 144 | 371 | 326 |
| | | | 4816 | 366 | 108 | 0 | 0 | 3567 | 3079 | 1.50 | 1.70 | 1.13 | 1.27 | 148 | 155 | 654 | 507 |
| | | | 3612 | 86 | 65 | 0 | 0 | 2614 | 2382 | 1.53 | 1.53 | .80 | 1.13 | 151 | 152 | 539 | 479 |

STATION D-6 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M³ DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 MAY | 32 | 5.5 | 7503 | 1483 | 4678 | 130 | 81 | 7671 | 6901 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8769 | 929 | 9205 | 98 | 163 | 10222 | 7606 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 13447 | 2298 | 1793 | 130 | 0 | 8791 | 7120 | -- | -- | -- | -- | -- | -- | -- | -- |
| 24 JUNE | 36 | 14.7 | 2408 | 817 | 1118 | 22 | 0 | 3750 | 2735 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6816 | 1355 | 2709 | 22 | 0 | 7914 | 6269 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5397 | 1075 | 1032 | 108 | 0 | 7837 | 6656 | -- | -- | -- | -- | -- | -- | -- | -- |
| 15 JULY | 34 | 16.4 | 7009 | 2064 | 1355 | 151 | 0 | 8310 | 6757 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 11008 | 2662 | 1765 | 0 | 0 | 10268 | 7581 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | -1 | -1 | -1 | -1 | -1 | 7088 | 5412 | -- | -- | -- | -- | -- | -- | -- | -- |
| 12 AUG | 32 | 16.9 | 10019 | 1398 | 3247 | 86 | 0 | 11776 | 9701 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 11698 | 430 | 10406 | 0 | 0 | 15791 | 11614 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10514 | 1591 | 8644 | 151 | 0 | 16166 | 12584 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 SEPT | 36 | 18.1 | 7289 | 1118 | 2279 | 108 | 22 | 9533 | 7514 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5397 | 237 | 2150 | 43 | 0 | 8918 | 7289 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3225 | 430 | 323 | 22 | 0 | 5175 | 4655 | -- | -- | -- | -- | -- | -- | -- | -- |
| 6 OCT | 31 | 8.9 | 11056 | 1570 | 1161 | 0 | 0 | 12851 | 10677 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10985 | 1852 | 1871 | 22 | 0 | 12191 | 5585 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 12836 | 959 | 9139 | 22 | 0 | 13422 | 11369 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7 NOV | 32 | 7.8 | 17953 | 2881 | 3139 | 0 | 0 | 16521 | 13842 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7138 | 688 | 4945 | 108 | 0 | 10170 | 7484 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 15287 | 1484 | 4988 | 22 | 0 | 17974 | 14985 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION E-1 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M³ DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 APR | 95 | 1.7 | 3561 | 1011 | 1418 | 147 | 0 | 2981 | 1520 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4450 | 804 | 799 | 130 | 0 | 2068 | 1894 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5281 | 1728 | 1483 | 114 | 0 | 3117 | 2031 | -- | -- | -- | -- | -- | -- | -- | -- |
| 24 MAY | 46 | 3.3 | 4499 | 1744 | 3602 | 489 | 33 | 8241 | 6306 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5102 | 815 | 4417 | 49 | 0 | 9702 | 6548 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7465 | 1483 | 3450 | 163 | 0 | 10789 | 8160 | -- | -- | -- | -- | -- | -- | -- | -- |
| 21 JUNE | 41 | 8.4 | 3505 | 1699 | 1333 | 22 | 0 | 8260 | 6775 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2967 | 1527 | 753 | 0 | 0 | 5771 | 4709 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2129 | 1591 | 1849 | 0 | 0 | 8467 | 7011 | -- | -- | -- | -- | -- | -- | -- | -- |
| 18 JULY | 46 | 17.2 | 5160 | 1247 | 1118 | 0 | 0 | 2881 | 4132 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 13416 | 1617 | 1763 | 26 | 129 | 9292 | 7282 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 19909 | 172 | 5418 | 43 | 0 | 8020 | 10169 | -- | -- | -- | -- | -- | -- | -- | -- |
| 14 AUG | 40 | 16.9 | 5074 | 731 | 4429 | 22 | 0 | 9660 | 6775 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3208 | 1183 | 387 | 43 | 0 | 7009 | 6330 | -- | -- | -- | -- | -- | -- | - | -- |
| | | | 8450 | 1527 | 6363 | 108 | 0 | 14532 | 11563 | -- | -- | -- | -- | -- | -- | -- | -- |
| 16 SEPT | 43 | 13.0 | 7912 | 800 | 3741 | 237 | 0 | 10550 | 8591 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7375 | 2215 | 3591 | 151 | 0 | 10868 | 8839 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8256 | 387 | 4042 | 65 | 0 | 9709 | 7751 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 OCT | 40 | 12.9 | 6386 | 1054 | 2258 | 430 | 0 | 9490 | 7230 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5332 | 1183 | 2258 | 430 | 43 | 7488 | 5846 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4752 | 817 | 473 | 129 | 22 | 7570 | 6717 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9 NOV | 47 | 8.0 | 10019 | 2127 | 4042 | 237 | 43 | 12965 | 10073 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7482 | 1548 | 1806 | 108 | 0 | 10499 | 8927 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9632 | 1140 | 2494 | 323 | 0 | 10931 | 9236 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION E-2 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M³ DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 APR | 170 | 1.5 | 4022 | 764 | 164 | 91 | 0 | 2854 | 1667 | 1.63 | -1.00 | 1.03 | -1.00 | 175 | 171 | 508 | 467 |
| | | | 4368 | 5278 | 364 | 109 | 0 | 4575 | 3693 | 1.70 | -1.00 | .67 | -1.00 | 170 | 156 | 722 | 641 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.30 | -1.00 | .47 | -1.00 | 161 | 192 | -1 | -1 |
| 9 MAY | 196 | 2.6 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.20 | 2.27 | .70 | .87 | 158 | 180 | 2445 | 2239 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.97 | 2.33 | .90 | 1.00 | 169 | 146 | 2380 | 2145 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.77 | 2.10 | .70 | .70 | 157 | 166 | 2684 | 2418 |
| 24 MAY | 201 | 3.1 | 1174 | 65 | 49 | 33 | 0 | 626 | 507 | 1.07 | 1.60 | .37 | .70 | 162 | 152 | 1393 | 1308 |
| | | | 587 | 49 | 33 | 16 | 0 | 329 | 253 | 1.23 | 1.43 | .43 | .77 | 160 | 178 | 1393 | 1161 |
| | | | 766 | 65 | 16 | 0 | 0 | 510 | 434 | 1.57 | 1.23 | .80 | .40 | 169 | 162 | 1367 | 1259 |
| 21 JUNE | 200 | 8.9 | 430 | 301 | 0 | 22 | 0 | 544 | 449 | 2.23 | 1.63 | 1.20 | .73 | 206 | 205 | 1069 | 841 |
| | | | 1312 | 409 | 22 | 22 | 0 | 968 | 858 | 2.03 | 1.67 | 1.27 | .67 | 215 | 214 | 1186 | 1038 |
| | | | 1570 | 817 | 301 | 0 | 0 | 1359 | 1054 | 1.80 | 1.40 | 1.03 | .70 | 220 | 203 | 1175 | 1025 |
| 18 JULY | 203 | 15.1 | 731 | 0 | 215 | 0 | 0 | 572 | 340 | 1.30 | .97 | .70 | .53 | 154 | 144 | 486 | 447 |
| | | | 258 | 0 | 0 | 0 | 0 | 120 | 95 | 1.50 | 1.00 | .80 | .63 | 158 | 160 | 1363 | 1292 |
| | | | 2365 | 86 | 129 | 0 | 0 | 1131 | 819 | 1.53 | .73 | .90 | .40 | 162 | 162 | 1177 | 807 |
| 14 AUG | 189 | 16.3 | 753 | 194 | 22 | 0 | 0 | 510 | 454 | 1.27 | .93 | .70 | .67 | 181 | 178 | 229 | 190 |
| | | | 1312 | 22 | 65 | 0 | 0 | 1060 | 937 | 1.30 | .77 | .70 | .43 | 180 | 190 | 230 | 191 |
| | | | 1441 | 43 | 65 | 0 | 0 | 1109 | 995 | 1.63 | .97 | .93 | .63 | 178 | 174 | 262 | 205 |
| 16 SEPT | 202 | 14.5 | 1333 | 172 | 65 | 43 | 0 | 1144 | 1004 | 1.80 | 1.33 | 1.10 | .93 | 151 | 159 | 2536 | 2337 |
| | | | 1204 | 151 | 22 | 22 | 0 | 1223 | 1116 | 1.97 | 1.30 | 1.23 | .73 | 180 | 172 | 1682 | 1488 |
| | | | 1634 | 65 | 43 | 0 | 0 | 1484 | 1305 | 2.00 | 1.50 | .93 | .97 | 153 | 197 | 2317 | 2097 |
| 4 OCT | 201 | 13.0 | 2451 | 215 | 172 | 0 | 0 | 2058 | 1780 | 3.90 | 1.67 | 1.63 | 1.30 | 142 | 161 | 1275 | 1163 |
| | | | 2107 | 344 | 301 | 0 | 0 | 1937 | 1557 | 3.10 | 1.70 | 1.47 | 1.10 | 147 | 154 | 762 | 670 |
| | | | 1398 | 452 | 22 | 0 | 0 | 1004 | 901 | 3.00 | 1.57 | 1.03 | .83 | 147 | 134 | 670 | 527 |
| 9 NOV | 201 | 7.2 | 602 | 194 | 43 | 0 | 0 | 458 | 402 | 1.83 | .93 | 1.37 | .67 | 156 | 165 | 1298 | 1125 |
| | | | 2623 | 301 | 86 | 0 | 0 | 1933 | 1673 | 1.37 | 1.27 | .83 | .67 | 152 | 161 | 1755 | 1594 |
| | | | 2516 | 301 | 43 | 0 | 0 | 2167 | 1572 | 1.03 | 1.47 | .67 | .80 | 155 | 158 | 1474 | 1327 |

STATION E-3 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M³ DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 APR | 260 | 1.8 | 364 | 291 | 0 | 0 | 0 | 526 | 371 | 1.00 | 1.13 | .67 | .60 | 174 | 173 | 450 | 413 |
| | | | 291 | 382 | 18 | 18 | 0 | 546 | 408 | 1.33 | 1.20 | 1.03 | .93 | 165 | 187 | 490 | 432 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .83 | 1.23 | .60 | .60 | 185 | 198 | 436 | 399 |
| 9 MAY | 274 | 2.5 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.13 | .90 | .83 | .70 | 152 | 184 | 990 | 913 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.00 | .83 | .87 | .63 | 144 | 157 | 1111 | 1037 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.03 | .87 | .87 | .57 | 187 | 168 | 939 | 869 |
| 25 MAY | 271 | 2.5 | 570 | 65 | 16 | 0 | 0 | 412 | 326 | 1.33 | .87 | .60 | -1.00 | 169 | 141 | 1744 | 1603 |
| | | | 619 | 81 | 0 | 0 | 0 | 344 | 272 | 1.03 | .87 | .53 | .57 | 148 | 183 | 1403 | 1282 |
| | | | 456 | 16 | 0 | 16 | 33 | 168 | 145 | .87 | .83 | .63 | .50 | 178 | 155 | 1598 | 1433 |
| 22 JUNE | 265 | 3.5 | 65 | 43 | 0 | 0 | 0 | 26 | 30 | .90 | 1.30 | .53 | .77 | 196 | 222 | 1404 | 1306 |
| | | | 968 | 43 | 0 | 0 | 0 | 340 | 301 | .73 | 1.27 | .60 | .57 | 204 | 212 | 1458 | 1282 |
| | | | 366 | 0 | 22 | 22 | 0 | 187 | 159 | .87 | 1.13 | .63 | .77 | 192 | 196 | 1197 | 1097 |
| 18 JULY | 261 | 15.0 | 817 | 0 | 43 | 0 | 0 | 198 | 163 | 1.47 | .87 | .73 | .57 | 150 | 150 | 1068 | 1031 |
| | | | 473 | 0 | 0 | 0 | 0 | 95 | 77 | 1.33 | .77 | .67 | .77 | 149 | 156 | 2696 | 2621 |
| | | | 1677 | 86 | 0 | 0 | 0 | 434 | 361 | 1.53 | .87 | .97 | .70 | 144 | 149 | 2745 | 2653 |
| 14 AUG | 265 | 17.4 | 387 | 0 | 0 | 0 | 0 | 273 | 234 | 1.70 | .67 | .90 | .33 | 177 | 202 | 512 | 422 |
| | | | 473 | 0 | 0 | 0 | 0 | 211 | 174 | 1.57 | .73 | .87 | .43 | 181 | 192 | 438 | 381 |
| | | | 65 | 0 | 0 | 0 | 0 | 43 | 37 | 1.17 | .83 | .53 | .43 | 175 | 189 | 318 | 273 |
| 16 SEPT | 265 | 15.3 | 452 | 0 | 0 | 0 | 0 | 237 | 206 | 2.03 | 1.33 | 1.00 | .97 | 170 | 147 | 1654 | 1563 |
| | | | 559 | 108 | 0 | 0 | 0 | 389 | 346 | 2.50 | 1.20 | 1.17 | .97 | 136 | 168 | 1214 | 1160 |
| | | | 452 | 22 | 0 | 22 | 0 | 331 | 295 | 2.10 | 1.17 | 1.10 | .73 | 160 | 138 | 1287 | 1205 |
| 5 OCT | 265 | 12.2 | 538 | 0 | 43 | 0 | 0 | 370 | 329 | 2.30 | 1.00 | 1.33 | .70 | 167 | 138 | 1171 | 1102 |
| | | | 129 | 0 | 0 | 0 | 0 | 69 | 65 | 2.20 | 2.07 | 1.27 | 1.87 | 150 | 149 | 1809 | 1723 |
| | | | 645 | 22 | 0 | 0 | 0 | 473 | 428 | 1.97 | 1.00 | 1.03 | .77 | 97 | 147 | 1401 | 1326 |
| 9 NOV | 268 | 9.0 | 710 | 129 | 0 | 0 | 0 | 725 | 626 | 1.43 | .93 | 1.00 | .73 | 159 | 172 | 1273 | 1161 |
| | | | 538 | 258 | 0 | 0 | 0 | 649 | 553 | 1.57 | .70 | 1.07 | .63 | 179 | 162 | 1799 | 1683 |
| | | | 688 | 22 | 0 | 0 | 0 | 286 | 256 | 1.10 | .83 | .73 | .63 | 165 | 164 | 1329 | 1222 |

STATION E-4 1965

| DATE | DPTH METR | SFC TEMP C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 APR | 223 | 2.1 | -1 | -1 | -1 | -1 | -1 | 29 | 11 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1183 | 16 | 0 | 0 | 0 | 293 | 227 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 728 | 18 | 0 | 0 | 0 | 193 | 160 | -- | -- | -- | -- | -- | -- | -- | -- |
| 25 MAY | 203 | 2.5 | 929 | 0 | 0 | 0 | 0 | 328 | 238 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1043 | 0 | 0 | 16 | 0 | 386 | 292 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 261 | 16 | 0 | 0 | 0 | 171 | 111 | -- | -- | -- | -- | -- | -- | -- | -- |
| 22 JUNE | 213 | 3.0 | 366 | 0 | 0 | 0 | 0 | 170 | 151 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 710 | 0 | 0 | 0 | 0 | 320 | 286 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 624 | 0 | 0 | 0 | 0 | 277 | 243 | -- | -- | -- | -- | -- | -- | -- | -- |
| 18 JULY | 213 | 15.3 | 1247 | 0 | 215 | 0 | 0 | 340 | 241 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1591 | 0 | 172 | 0 | 0 | 357 | 245 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 903 | 0 | 86 | 0 | 0 | 288 | 194 | -- | -- | -- | -- | -- | -- | -- | -- |
| 14 AUG | 214 | 17.5 | 581 | 0 | 0 | 22 | 0 | 615 | 559 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 366 | 0 | 0 | 0 | 0 | 368 | 325 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 430 | 0 | 0 | 0 | 0 | 325 | 286 | -- | -- | -- | -- | -- | -- | -- | -- |
| 16 SEPT | 240 | 15.5 | 559 | 0 | 0 | 0 | 0 | 527 | 479 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 387 | 0 | 0 | 0 | 0 | 256 | 243 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 215 | 0 | 0 | 0 | 0 | 88 | 95 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5 OCT | 227 | 12.3 | 108 | 0 | 0 | 0 | 0 | 71 | 62 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 710 | 0 | 0 | 0 | 0 | 602 | 538 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 280 | 0 | 22 | 0 | 0 | 168 | 142 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION E-5 1965

| DATE | DPTH METR | SFC TEMP C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 APR | 150 | 1.6 | 3130 | 601 | 55 | 91 | 0 | 1913 | 1609 | 1.30 | 1.23 | .90 | .70 | 182 | 185 | 176 | 118 |
| | | | 3003 | 1128 | 36 | 200 | 0 | 2100 | 1747 | 1.10 | 1.07 | .90 | .77 | 167 | 189 | 71 | 51 |
| | | | 1401 | 218 | 36 | 55 | 0 | 1176 | 1039 | 1.17 | .95 | .77 | .50 | 164 | 153 | 185 | 142 |
| 9 MAY | 168 | 2.2 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.17 | .83 | .73 | .53 | 171 | 137 | 986 | 922 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .87 | .87 | .53 | .40 | 181 | 173 | 864 | 797 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.00 | .80 | .6[illegible] | .40 | 163 | 184 | 1031 | 926 |
| 25 MAY | 180 | 2.5 | 244 | 49 | 244 | 0 | 0 | 336 | 287 | 1.37 | 1.53 | .67 | .77 | 173 | 167 | 1062 | 944 |
| | | | 424 | 0 | 49 | 0 | 0 | 302 | 194 | 1.33 | 1.23 | .73 | .83 | 169 | 168 | 491 | 437 |
| | | | 1500 | 16 | 16 | 0 | 0 | 1043 | 877 | .90 | 1.30 | .47 | .80 | 179 | 154 | 1209 | 1024 |
| 22 JUNE | 175 | 10.2 | 1871 | 473 | 0 | 22 | 0 | 1748 | 1548 | 1.20 | 1.47 | .50 | .83 | 154 | 160 | 942 | 777 |
| | | | 1247 | 129 | 22 | 0 | 0 | 776 | 682 | 1.30 | 1.43 | .70 | .87 | 152 | 164 | 1188 | 1034 |
| | | | 1054 | 129 | 22 | 22 | 0 | 1101 | 985 | 1.20 | 1.23 | .60 | .60 | 146 | 125 | 737 | 662 |
| 17 JULY | 183 | 15.2 | 4128 | 0 | 0 | 0 | 0 | 2077 | 1724 | 1.63 | .97 | .70 | .53 | 144 | 135 | 433 | 381 |
| | | | 2666 | 86 | 43 | 0 | 0 | 740 | 628 | 1.30 | .80 | .70 | .63 | 158 | 162 | 444 | 396 |
| | | | 3311 | 215 | 43 | 0 | 0 | 1213 | 1015 | 1.47 | .90 | .80 | .63 | 158 | 137 | 559 | 522 |
| 13 AUG | 175 | 17.8 | 1720 | 194 | 65 | 43 | 0 | 1739 | 1587 | 1.53 | .80 | .77 | .30 | 192 | 196 | 191 | 144 |
| | | | 1656 | 43 | 0 | 43 | 0 | 1279 | 1174 | 1.70 | 1.00 | .93 | .50 | 200 | 215 | 308 | 238 |
| | | | 1441 | 301 | 108 | 0 | 0 | 1144 | 1002 | 1.23 | .77 | .73 | .40 | 215 | 231 | 169 | 125 |
| 16 SEPT | 174 | 15.0 | 968 | 22 | 65 | 0 | 0 | 768 | 664 | 2.47 | 2.37 | 1.47 | 1.67 | 153 | 150 | 1516 | 1169 |
| | | | 1828 | 43 | 65 | 0 | 0 | 1754 | 1615 | 2.83 | 1.47 | 1.37 | 1.17 | 168 | 159 | 421 | 370 |
| | | | 1484 | 0 | 43 | 22 | 0 | 1256 | 1155 | 2.33 | 2.17 | 1.17 | 1.27 | 190 | 192 | 805 | 763 |
| 5 OCT | 174 | 11.6 | 1204 | 43 | 86 | 0 | 0 | 1198 | 1066 | 1.90 | .93 | 1.13 | .73 | 165 | 162 | 963 | 885 |
| | | | 1376 | 65 | 215 | 0 | 0 | 1372 | 1256 | 2.00 | .87 | 1.07 | .63 | 160 | 153 | 573 | 537 |
| | | | 1699 | 86 | 0 | 0 | 0 | 1858 | 1699 | 1.50 | .93 | .87 | .73 | 170 | 173 | 293 | 252 |
| 8 NOV | 175 | 8.9 | 1957 | 108 | 86 | 0 | 0 | 1634 | 1468 | 4.10 | 1.23 | 2.83 | .90 | 164 | 161 | 1917 | 1771 |
| | | | 1892 | 22 | 129 | 0 | 0 | 1705 | 1552 | 1.27 | 1.13 | .93 | .80 | 175 | 178 | 2297 | 2102 |
| | | | 1548 | 22 | 0 | 0 | 0 | 1043 | 980 | 1.03 | .70 | .77 | .53 | 170 | 159 | 1657 | 1534 |

STATION E-6 1965

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 APR | 31 | 2.6 | 5606 | 3767 | 3513 | 710 | 36 | 9637 | 6456 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6752 | 3294 | 6042 | 619 | 18 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6170 | 2584 | 2106 | 510 | 0 | 7052 | 4859 | -- | -- | -- | -- | -- | -- | -- | -- |
| 25 MAY | 33 | 7.3 | 9258 | 1451 | 5689 | 81 | 33 | 11286 | 8204 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8231 | 342 | 3965 | 81 | 0 | 10567 | 7430 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9992 | 1483 | 6096 | 375 | 0 | 13746 | 10126 | -- | -- | -- | -- | -- | -- | -- | -- |
| 22 JUNE | 37 | 11.2 | 1656 | 710 | 1161 | 43 | 0 | 2608 | 1726 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3612 | 1591 | 2172 | 0 | 65 | 6831 | 4317 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6128 | 2060 | 2344 | 0 | 0 | 7510 | 5863 | -- | -- | -- | -- | -- | -- | -- | -- |
| 17 JULY | 37 | 12.2 | 14749 | 2279 | 3612 | 86 | 0 | 10961 | 5163 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9589 | 3741 | 3655 | 0 | 43 | 9340 | 7048 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 15067 | 2279 | 5676 | 301 | 43 | 10651 | 7564 | -- | -- | -- | -- | -- | -- | -- | -- |
| 13 AUG | 37 | 14.0 | 11266 | 4066 | 7763 | 129 | 43 | 18770 | 14175 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10019 | 455 | 4752 | 43 | 0 | 15504 | 11638 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10191 | 1935 | 7869 | 22 | 0 | 16271 | 12356 | -- | -- | -- | -- | -- | -- | -- | -- |
| 15 SEPT | 36 | 13.9 | 7719 | 516 | 1957 | 129 | 0 | 10649 | 9159 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8450 | 3032 | 2129 | 129 | 0 | 16192 | 13680 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 11438 | 582 | 3075 | 151 | 0 | 16243 | 13685 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5 OCT | 32 | 7.7 | 9763 | 774 | 10428 | 0 | 0 | 13530 | 9125 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4945 | 387 | 4150 | 43 | 0 | 6413 | 3935 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10041 | 731 | 3892 | 0 | 0 | 10888 | 8226 | -- | -- | -- | -- | -- | -- | -- | -- |
| 8 NOV | 33 | 7.6 | 10772 | 1056 | 4279 | 22 | 0 | 11718 | 9000 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7396 | 1849 | 3578 | 129 | 22 | 11223 | 8052 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10363 | 2193 | 5536 | 151 | 22 | 16022 | 11806 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION A-1 196

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 MARCH | 19 | 2.1 | 323 | 344 | 344 | 22 | 43 | 576 | 372 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 237 | 65 | 344 | 65 | 0 | 361 | 247 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 108 | 65 | 86 | 0 | 0 | 196 | 112 | -- | -- | -- | -- | -- | -- | -- | -- |
| 29 APR | 18 | 9.2 | 194 | 237 | 151 | 22 | 0 | 4401 | 604 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 43 | 301 | 258 | 129 | 43 | 396 | 237 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1957 | 1333 | 1011 | 258 | 22 | 8437 | 1428 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 JUNE | 17 | 16.7 | 9052 | 946 | 151 | 151 | 0 | 8290 | 1223 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5332 | 688 | 108 | 108 | 0 | 3421 | 897 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7482 | 1247 | 172 | 108 | 0 | 2780 | 1131 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION A-2 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 MARCH | 35 | 2.0 | 5397 | 3010 | 10406 | 323 | 0 | 14113 | 6517 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6472 | 4257 | 11976 | 237 | 0 | 12777 | 6001 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7009 | 3849 | 4171 | 280 | 0 | 13754 | 7787 | -- | -- | -- | -- | -- | -- | -- | -- |
| 29 APR | 33 | 5.7 | 4214 | 4773 | 3376 | 387 | 0 | 17037 | 8308 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4730 | 3827 | 2774 | 215 | 0 | 13285 | 7461 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5139 | 2989 | 3376 | 215 | 0 | 12924 | 7013 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 JUNE | 32 | 14.2 | 6472 | 4945 | 10105 | 538 | 0 | 13721 | 8237 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4580 | 3032 | 4085 | 645 | 0 | 12038 | 7869 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4666 | 2881 | 3311 | 366 | 0 | 11429 | 7263 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION A-3 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 MARCH | 69 | 2.3 | 4429 | [illegible] | 1353 | 373 | 0 | 5547 | 3538 | 2.57 | 3.49 | 1.10 | .73 | 170 | 154 | 48 | 26 |
| | | | 3866 | 520 | 2376 | 215 | 0 | 8704 | 3145 | 2.33 | 2.47 | .73 | .80 | 149 | 145 | 29 | 13 |
| | | | 5611 | [illegible] | 1059 | 172 | 0 | 4710 | 3711 | 2.27 | 2.33 | .70 | .83 | 152 | 149 | 31 | 14 |
| 16 APR | 69 | 2.7 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.07 | 2.04 | .73 | 1.00 | 160 | 154 | 67 | 20 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.73 | 2.83 | .97 | 1.37 | 151 | 170 | 259 | 216 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.57 | 2.49 | 1.22 | 1.30 | 150 | 156 | 193 | 159 |
| 29 APR | 65 | 7.6 | 3755 | 645 | 117 | 344 | 0 | 5346 | 3564 | 2.43 | 2.67 | .67 | .93 | 165 | 169 | -1 | -1 |
| | | | 4238 | 1675 | 611 | 129 | 0 | 5501 | 4519 | 2.27 | 2.23 | .77 | .80 | 156 | 159 | -1 | -1 |
| | | | 5391 | 817 | 1355 | 258 | 0 | 4646 | 3666 | 2.13 | 2.17 | .83 | .83 | 136 | 144 | -1 | -1 |
| 19 MAY | 61 | 7.[illegible] | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.50 | 3.45 | 1.10 | .80 | 149 | 151 | 238 | 160 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.27 | 2.23 | .93 | .73 | 161 | 178 | 312 | 191 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.43 | 2.17 | 1.20 | .90 | 152 | 166 | 277 | 183 |
| 6 JUNE | 77 | 14.[illegible] | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.57 | .73 | 1.57 | 1.17 | 166 | 147 | -1 | -1 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.73 | 1.47 | 1.40 | .80 | 146 | 163 | -1 | -1 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.33 | 2.67 | 1.23 | 1.30 | 165 | 156 | -1 | -1 |

STATION A-4 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 MARCH | 75 | 2.5 | 3678 | 172 | 581 | 194 | 0 | 2176 | 1651 | 2.17 | 2.80 | .67 | 1.00 | 163 | 149 | 42 | 26 |
| | | | 3118 | 86 | 409 | 43 | 0 | 1996 | 1507 | 2.47 | 2.30 | .97 | .77 | 160 | 160 | 54 | 42 |
| | | | 3684 | 172 | 194 | 22 | 0 | 1668 | 1362 | 2.00 | 2.13 | .43 | .90 | 148 | 160 | 23 | 14 |
| 16 APR | 74 | 2.4 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.17 | 2.30 | .90 | 1.10 | 168 | 160 | 371 | 319 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.77 | 2.60 | .77 | 1.07 | 159 | 165 | 213 | 193 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.23 | 2.07 | .90 | .93 | 156 | 148 | 137 | 103 |
| 26 APR | 69 | 4.0 | 2709 | 409 | 108 | 138 | 0 | 1412 | 1464 | 1.77 | 2.10 | .03 | .80 | 165 | 165 | 651 | 599 |
| | | | 1656 | 301 | 22 | 22 | 0 | 4247 | 2505 | 2.20 | 2.10 | .87 | .80 | -1 | -1 | 761 | 709 |
| | | | 6773 | 710 | 904 | 215 | 0 | 3391 | 2526 | 2.24 | 2.23 | .83 | .70 | 149 | 151 | -1 | -1 |
| 18 MAY | 61 | 6.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.73 | 2.07 | .60 | .63 | 140 | 140 | 394 | 300 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.83 | 1.93 | .73 | .67 | 151 | 161 | 404 | 334 |
| | | | -1 | -1 | -1 | -1 | -1 | 1 | -1 | 1.73 | 1.70 | .73 | .43 | 156 | 142 | 341 | 261 |
| 6 JUNE | 69 | 12.8 | 4128 | 22 | 667 | 86 | 0 | 4409 | 3365 | 1.67 | 1.47 | .77 | .70 | 170 | 170 | 161 | 141 |
| | | | 6386 | 151 | 839 | 65 | 0 | 4754 | 4136 | 1.83 | 1.63 | .90 | .77 | 186 | 184 | 148 | 133 |
| | | | 4150 | 129 | 439 | 172 | 0 | 3537 | 2956 | 1.57 | 1.23 | .97 | .67 | 171 | 166 | 117 | 106 |

STATION A-5 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 APR | 38 | 3.5 | 6467 | 1032 | 1763 | 151 | 0 | 5575 | 5080 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2967 | 1441 | 1028 | 473 | 0 | 4711 | 2986 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5203 | 1354 | 1312 | 366 | 0 | 6566 | 4595 | -- | -- | -- | -- | -- | -- | -- | -- |
| 6 JUNE | 40 | 14.5 | 6558 | 645 | 624 | 151 | 0 | 5777 | 4625 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9611 | 1720 | 1557 | 151 | 0 | 8484 | 6665 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4666 | 1161 | 1634 | 22 | 0 | 6960 | 5680 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION A-6 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 MARCH | 19 | 2.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 7.70 | -1.00 | 1.43 | -1.00 | 170 | -1 | 39 | 16 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 7.97 | -1.00 | 1.70 | -1.00 | 160 | -1 | 72 | 43 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 7.03 | -1.00 | 1.67 | -1.00 | 159 | -1 | 52 | 33 |
| 16 APR | 18 | 3.6 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.30 | -1.00 | 1.37 | -1.00 | 168 | -1 | 139 | 100 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.67 | -1.00 | 1.17 | -1.00 | 179 | -1 | 95 | 46 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.30 | -1.00 | 1.37 | -1.00 | 168 | -1 | 28 | 12 |
| 26 APR | 17 | 6.6 | 667 | 290 | 409 | 22 | 0 | 4637 | 1269 | 3.97 | -1.00 | 1.90 | -1.00 | 165 | -1 | 52 | 9 |
| | | | 3139 | 129 | 129 | 86 | 0 | 2074 | 1026 | 3.77 | -1.00 | 1.67 | -1.00 | 160 | -1 | 25 | 5 |
| | | | 1312 | 108 | 43 | 22 | 0 | 5951 | 2507 | 3.47 | -1.00 | 1.53 | -1.00 | 161 | -1 | 29 | 0 |
| 17 MAY | 14 | 8.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.50 | -1.00 | 1.43 | -1.00 | 148 | -1 | 131 | 72 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.50 | -1.00 | 1.43 | -1.00 | 162 | -1 | 69 | 30 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.20 | -1.00 | 1.10 | -1.00 | 159 | -1 | 61 | 23 |
| 6 JUNE | 18 | 15.0 | 22 | 0 | 0 | 0 | 0 | 0 | 503 | 2.10 | -1.00 | 1.23 | -1.00 | 147 | -1 | 32 | 18 |
| | | | 7912 | 43 | 0 | 0 | 0 | 595 | 140 | 1.97 | -1.00 | 1.27 | -1.00 | 162 | -1 | 21 | 12 |
| | | | 2122 | 129 | 0 | 0 | 0 | 159 | 0 | 1.77 | -1.00 | 1.17 | -1.00 | 150 | -1 | 28 | 18 |

STATION B-1 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 MARCH | 23 | 1.8 | 7525 | 172 | 2344 | 65 | 55 | 8394 | 5242 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8493 | 237 | 2906 | 43 | 22 | 11543 | 6429 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 8149 | 301 | 1762 | 0 | 22 | 7557 | 5319 | -- | -- | -- | -- | -- | -- | -- | -- |
| 29 APR | 18 | 6.0 | 2129 | 86 | 215 | 65 | 0 | 2356 | 1490 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 215 | 3462 | 1075 | 22 | 0 | 13384 | 4539 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1376 | 65 | 215 | 0 | 0 | 1355 | 970 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 JUNE | 20 | 10.0 | 7052 | 21 | 387 | 22 | 0 | 3339 | 2066 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 15738 | 344 | 559 | 86 | 0 | 6134 | 4926 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 11735 | 65 | 258 | 65 | 0 | 3618 | 2776 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION B-2 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 MARCH | 54 | 1.5 | 5203 | 366 | 2580 | 258 | 0 | 4586 | 3083 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3591 | 172 | 2451 | 237 | 0 | 3393 | 2148 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4515 | 495 | 3225 | 258 | 0 | 4186 | 2717 | -- | -- | -- | -- | -- | -- | -- | -- |
| 29 APR | 46 | 3.0 | 4685 | 1355 | 5540 | 753 | 0 | 7160 | 4743 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3612 | 1226 | 2731 | 559 | 0 | 6527 | 4542 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3548 | 1183 | 3333 | 473 | 22 | 6983 | 4868 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 JUNE | 46 | 12.1 | 4601 | 2559 | 4343 | 624 | 0 | 7469 | 5091 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3806 | 1548 | 3544 | 882 | 0 | 7680 | 5444 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3806 | 1312 | 3999 | 753 | 0 | 6947 | 4818 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION B-3 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 29 MARCH | 70 | 2.0 | 3612 | 710 | 1011 | 538 | 0 | 2421 | 1821 | 2.63 | 2.07 | .93 | .57 | 160 | 173 | 36 | 25 |
| | | | 2602 | 280 | 925 | 151 | 0 | 2189 | 1664 | 2.43 | 2.20 | .83 | .57 | 164 | 170 | 23 | 11 |
| | | | 1656 | 86 | 946 | 172 | 0 | 1475 | 1066 | 2.40 | 2.43 | .80 | .73 | 155 | 162 | 31 | 15 |
| 15 APR | 60 | 2.8 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.40 | 2.47 | .53 | .73 | 141 | 153 | 314 | 276 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.13 | 2.0[illegible] | .67 | .63 | 164 | 163 | 478 | 440 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.40 | 2.13 | .83 | .70 | 154 | 150 | 515 | 472 |
| 29 APR | 67 | 4.0 | 4128 | 538 | 1333 | 215 | 0 | 3982 | 3025 | 2.63 | 2.47 | .87 | .80 | 141 | 158 | 184 | 167 |
| | | | 5612 | 1591 | 1828 | 280 | 0 | 4253 | 3201 | 2.37 | 2.50 | .63 | .63 | 160 | 170 | 236 | 215 |
| | | | 3827 | 796 | 1914 | 430 | 0 | 4317 | 3262 | 2.40 | 2.13 | .67 | .57 | 155 | 159 | 198 | 180 |
| 16 MAY | 68 | 5.4 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 4.83 | 4.93 | 1.13 | 1.37 | 141 | 151 | 499 | 442 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 5.73 | 4.97 | 1.90 | 1.03 | 137 | 142 | 642 | 585 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 4.13 | 4.60 | 1.20 | .97 | 141 | 142 | 723 | 637 |
| 4 JUNE | 62 | 10.5 | 6429 | 1441 | 1871 | 495 | 0 | 5975 | 4805 | 5.17 | 7.37 | 2.47 | 4.37 | 156 | 168 | 266 | 195 |
| | | | 5096 | 753 | 1312 | 280 | 0 | 5117 | 4104 | 3.53 | 2.43 | 1.53 | 1.00 | 152 | 156 | 157 | 129 |
| | | | 3764 | 989 | 11[illegible]3 | 534 | 0 | 4299 | 3337 | 2.23 | 2.57 | 1.07 | .83 | 153 | 145 | 199 | 179 |

STATION B-4 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 29 MARCH | 130 | 3.1 | 1892 | 409 | 22 | 108 | 0 | 1324 | 1092 | 1.53 | 1.13 | .90 | .40 | 155 | 140 | 99 | 86 |
| | | | 1720 | 387 | 108 | 0 | 0 | 1410 | 1167 | 1.73 | 1.77 | .90 | .83 | 158 | 158 | 251 | 226 |
| | | | 1484 | 151 | 65 | 0 | 0 | 1142 | 914 | 1.00 | 1.20 | .00 | .43 | 156 | 142 | 87 | 74 |
| 15 APR | 133 | 3.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.63 | 1.67 | .90 | .67 | 148 | 153 | 579 | 524 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.43 | 1.73 | .93 | .87 | 167 | 150 | 673 | 620 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.67 | 1.33 | .90 | .53 | 155 | 155 | 658 | 610 |
| 30 APR | 128 | 3.9 | 1505 | 86 | 22 | 43 | 0 | 1090 | 965 | 1.60 | 1.47 | .70 | .47 | 158 | 140 | -1 | -1 |
| | | | 2580 | 1011 | 86 | 65 | 0 | 2427 | 2045 | 1.50 | 1.33 | .67 | .57 | 171 | 162 | 303 | 260 |
| | | | 1398 | 237 | 43 | 151 | 0 | 1107 | 962 | 1.37 | 1.30 | .77 | .47 | 168 | 147 | 276 | 234 |
| 16 MAY | 138 | 4.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.40 | 2.00 | .97 | .37 | 140 | 156 | 763 | 633 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.33 | 1.40 | 1.07 | .67 | 140 | 150 | 802 | 690 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.17 | 1.63 | .87 | .33 | 134 | 145 | 701 | 623 |
| 7 JUNE | 139 | 9.0 | 1785 | 624 | 0 | 22 | 0 | 2490 | 2174 | 1.23 | 1.23 | .53 | .60 | 142 | 156 | 647 | 603 |
| | | | 3419 | 482 | 0 | 65 | 0 | 3429 | 2965 | 1.20 | 1.13 | .50 | .43 | 140 | 168 | 354 | 324 |
| | | | 1419 | 172 | 43 | 22 | 0 | 1909 | 1660 | 1.37 | 1.07 | .60 | .40 | 166 | 157 | 366 | 335 |

STATION B-5 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 30 APR | 108 | 3.6 | 1692 | 366 | 194 | 172 | 0 | 1894 | 1589 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1312 | 344 | 86 | 86 | 0 | 1582 | 1314 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1484 | 559 | 215 | 151 | 0 | 1797 | 1464 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7 JUNE | 100 | 10.9 | 1828 | 237 | 43 | 172 | 0 | 2834 | 2554 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1484 | 108 | 86 | 215 | 0 | 2535 | 2251 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1527 | 344 | 65 | 172 | 0 | 2881 | 2563 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION B-6 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 25 MARCH | 86 | 2.1 | 2966 | 215 | 108 | 65 | 0 | 1931 | 1548 | 1.83 | 2.17 | .60 | .73 | 169 | 156 | -1 | -1 |
| | | | 2623 | 129 | 151 | 108 | 0 | 1406 | 1131 | 2.73 | 2.07 | .97 | .47 | 171 | 160 | -1 | -1 |
| | | | 3612 | 581 | 194 | 151 | 0 | 2296 | 1871 | 2.13 | 1.80 | .67 | .57 | -1 | -1 | -1 | -1 |
| 15 APR | 81 | 2.5 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.87 | 1.97 | .97 | .73 | 133 | 155 | 608 | 562 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.97 | 2.27 | 1.00 | .77 | 144 | 163 | 577 | 522 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.90 | 2.10 | .77 | .90 | 153 | 155 | 670 | 579 |
| 30 APR | 84 | 3.9 | 4601 | 151 | 237 | 237 | 0 | 3380 | 2922 | 2.03 | 1.67 | .83 | .66 | 156 | 152 | 246 | 197 |
| | | | 3741 | 645 | 452 | 194 | 0 | 2999 | 2496 | 1.83 | 1.60 | .63 | .37 | 158 | 185 | 146 | 114 |
| | | | 4300 | 516 | 194 | 172 | 0 | 2754 | 2363 | 1.80 | 1.60 | .67 | .50 | 168 | 176 | 261 | 229 |
| 17 MAY | 80 | 4.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.13 | 2.23 | .83 | .83 | 153 | 179 | 678 | 568 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.63 | 1.87 | 1.13 | .37 | 158 | 169 | 481 | 403 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.17 | 1.57 | .73 | .27 | 170 | 166 | 193 | 73 |
| 7 JUNE | 89 | 12.9 | 4451 | 301 | 108 | 258 | 0 | 3102 | 2750 | 2.10 | 1.30 | .70 | .63 | 146 | 151 | 104 | 79 |
| | | | 4193 | 258 | 151 | 129 | 0 | 3055 | 2685 | 1.67 | 1.37 | .83 | .60 | 157 | 143 | 171 | 157 |
| | | | 3546 | 108 | 86 | 194 | 0 | 2322 | 2081 | 1.80 | 1.43 | .73 | .60 | 162 | 159 | 184 | 159 |

STATION B-7 1966

| | | | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | DRY | | ASH FREE | | | | | |
| DATE | DPTH METR | SFC TEM C | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 25 MARCH | 46 | 1.8 | 4601 | 1699 | 2258 | 409 | 0 | 6306 | 4315 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6536 | 1011 | 1247 | 344 | 0 | 5080 | 3879 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3225 | 1226 | 323 | 108 | 0 | 3844 | 3016 | -- | -- | -- | -- | -- | -- | -- | -- |
| 30 APR | 37 | 4.0 | 4833 | 817 | 2043 | 409 | 0 | 5728 | 4263 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6149 | 1871 | 3290 | 258 | 0 | 7746 | 5212 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5741 | 946 | 2881 | 409 | 0 | 6183 | 4549 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7 JUNE | 44 | 11.9 | 4601 | 903 | 2365 | 172 | 0 | 6074 | 4840 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5483 | 1828 | 1914 | 280 | 0 | 5893 | 4760 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5590 | 1290 | 2258 | 151 | 0 | 6472 | 5220 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION B-8 1966

| | | | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | DRY | | ASH FREE | | | | | |
| DATE | DPTH METR | SFC TEM C | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 25 MARCH | 12 | -1.0 | 301 | 108 | 22 | 43 | 0 | 452 | 260 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 409 | 7206 | 2043 | 301 | 22 | 9795 | 3696 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 194 | 968 | 0 | 65 | 65 | 1453 | 817 | -- | -- | -- | -- | -- | -- | -- | -- |
| 30 APR | 9 | 7.1 | 151 | 2946 | 3634 | 65 | 0 | 16544 | 3739 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 172 | 2107 | 5225 | 65 | 0 | 16678 | 3294 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7 JUNE | 11 | 11.0 | 2666 | 2279 | 1032 | 0 | 0 | 10735 | 3044 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7052 | 6794 | 2129 | 43 | 86 | 21233 | 6912 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2838 | 9053 | 2365 | 129 | 0 | 23082 | 6781 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C-1 1966

| | | | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | DRY | | ASH FREE | | | | | |
| DATE | DPTH METR | SFC TEM C | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 21 MARCH | 23 | -1.0 | 1505 | 22 | 108 | 0 | 0 | 1621 | 1090 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2344 | 22 | 108 | 0 | 0 | 2002 | 1778 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3763 | 108 | 1548 | 22 | 0 | 5820 | 3236 | -- | -- | -- | -- | -- | -- | -- | -- |
| 25 APR | 24 | 4.8 | 23693 | 215 | 1118 | 129 | 0 | 9503 | 7942 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |
| 1 JUNE | 21 | 6.8 | 1720 | 43 | 172 | 0 | 0 | 3769 | 3300 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6837 | 86 | 43 | 22 | 0 | 10350 | 9368 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5246 | 22 | 0 | 0 | 22 | 5923 | 5517 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C-2 1966

| | | | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | DRY | | ASH FREE | | | | | |
| DATE | DPTH METR | SFC TEM C | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 21 MARCH | 54 | -1.0 | 4580 | 3032 | 409 | 430 | 0 | 6112 | 4752 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7074 | 5375 | 86 | 323 | 0 | 9894 | 6652 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5977 | 3032 | 3698 | 516 | 0 | 8054 | 5504 | -- | -- | -- | -- | -- | -- | -- | -- |
| 25 APR | 52 | 3.2 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5471 | 6065 | 3999 | 989 | 0 | 5108 | 3132 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7697 | 1333 | 5289 | 2021 | 0 | 6536 | 4515 | -- | -- | -- | -- | -- | -- | -- | -- |
| 1 JUNE | 23 | 7.8 | 5117 | 1376 | 1720 | 753 | 0 | 6648 | 4672 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6020 | 1441 | 1505 | 817 | 0 | 8235 | 6448 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4924 | 1183 | 4739 | 538 | 0 | 7065 | 5822 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C-3 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 21 MARCH | 81 | 1.5 | 3892 | 301 | 366 | 215 | 0 | 2387 | 1894 | 3.90 | 2.60 | 1.63 | 1.53 | 128 | 123 | 899 | 819 |
| | | | 3591 | 473 | 624 | 237 | 0 | 2926 | 2187 | 3.50 | 2.53 | 2.07 | 1.00 | 132 | 127 | 1084 | 1021 |
| | | | 3247 | 516 | 516 | 172 | 0 | 2756 | 2184 | 3.07 | 2.43 | 1.03 | .97 | 128 | 124 | 1236 | 1153 |
| 12 APR | 82 | 2.1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 4.17 | 3.20 | 2.13 | 1.07 | 158 | 171 | 907 | 836 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 3.10 | 3.13 | 1.27 | 1.27 | 153 | 152 | 759 | 690 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.77 | 3.10 | 1.23 | 1.00 | 141 | 160 | 1180 | 1084 |
| 25 APR | 80 | 3.0 | 6235 | 1591 | 903 | 0 | 0 | 3466 | 2640 | 1.97 | 1.90 | .60 | .40 | 130 | 124 | 150 | 131 |
| | | | 4859 | 86 | 1118 | 387 | 43 | 1548 | 1140 | 1.53 | 1.97 | .37 | .47 | 124 | 130 | 189 | 174 |
| | | | 3053 | 43 | 602 | 43 | 86 | 1097 | 495 | 1.87 | 2.17 | .87 | .73 | 125 | 130 | 213 | 203 |
| 16 MAY | 81 | 4.5 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.10 | 2.17 | 1.00 | .67 | 163 | 153 | 23 | 19 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.80 | 2.03 | .67 | .83 | 155 | 150 | 90 | 81 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.23 | 1.97 | 1.03 | .63 | 139 | 156 | 20 | 13 |
| 1 JUNE | 80 | 6.5 | 3462 | 65 | 344 | 108 | 0 | 3122 | 2746 | 2.00 | 2.03 | .97 | .93 | 178 | 177 | 463 | 393 |
| | | | 3290 | 280 | 366 | 323 | 0 | 3857 | 3300 | 1.73 | 1.87 | .77 | .87 | 171 | 181 | 233 | 192 |
| | | | 3913 | 237 | 301 | 58 | 0 | 3958 | 3382 | 1.67 | 1.60 | .83 | .60 | 155 | 177 | 226 | 199 |

STATION C-4 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 21 MARCH | 102 | 1.5 | 3053 | 366 | 559 | 172 | 0 | 2318 | 1673 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2408 | 215 | 660 | 43 | 0 | 1875 | 1335 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2043 | 65 | 452 | 65 | 0 | 1585 | 1081 | -- | -- | -- | -- | -- | -- | -- | -- |
| 25 APR | 100 | 3.1 | 3698 | 129 | 774 | 129 | 0 | 899 | 654 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2795 | 0 | 215 | 86 | 0 | 985 | 701 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4730 | 86 | 1376 | 172 | 0 | 1660 | 1221 | -- | -- | -- | -- | -- | -- | -- | -- |
| 1 JUNE | 102 | 7.1 | 1806 | 667 | 538 | 22 | 0 | 2452 | 1825 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2555 | 258 | 409 | 86 | 0 | 3154 | 2672 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2322 | 172 | 237 | 22 | 0 | 1941 | 1636 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C-5 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 21 MARCH | 158 | 2.2 | 2215 | 301 | 108 | 0 | 0 | 1677 | 1387 | 2.30 | 1.57 | .77 | .83 | 124 | 130 | 775 | 697 |
| | | | 2193 | 817 | 0 | 43 | 0 | 1896 | 1589 | 1.97 | 1.63 | .73 | .60 | 144 | 147 | 618 | 575 |
| | | | 2107 | 516 | 0 | 108 | 0 | 1636 | 1404 | 1.70 | 1.63 | .60 | .60 | 139 | 144 | 911 | 848 |
| 14 APR | 160 | 2.0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.10 | 1.97 | 1.00 | .80 | 137 | 146 | 444 | 392 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.63 | 1.57 | .97 | .90 | 157 | 154 | 968 | 902 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.73 | 1.17 | 1.00 | .47 | 162 | 140 | 921 | 855 |
| 25 APR | 158 | 3.6 | 3870 | 129 | 215 | 0 | 86 | 1303 | 972 | 1.20 | 1.17 | .37 | .77 | 119 | 124 | 142 | 128 |
| | | | 3956 | 86 | 301 | 43 | 0 | 860 | 602 | 1.03 | 1.03 | .70 | .30 | 125 | 129 | 279 | 249 |
| | | | 4257 | 387 | 129 | 0 | 0 | 1660 | 1174 | 1.13 | 1.13 | .37 | .27 | 125 | 97 | 107 | 100 |
| 16 MAY | 158 | 4.5 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.60 | 2.07 | .70 | .83 | 166 | 176 | 308 | 278 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.53 | 2.00 | .67 | .73 | 169 | 178 | 143 | 120 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.57 | 2.23 | .63 | .87 | 157 | 158 | 84 | 69 |
| 1 JUNE | 159 | 7.2 | 1398 | 151 | 22 | 22 | 0 | 1217 | 1051 | 1.30 | 1.67 | .70 | .70 | 178 | 152 | 269 | 157 |
| | | | 2516 | 366 | 65 | 86 | 0 | 2144 | 1849 | 1.13 | 1.47 | .53 | .67 | 173 | 172 | 387 | 312 |
| | | | 2064 | 258 | 172 | 65 | 0 | 2494 | 2062 | 1.07 | 1.37 | .57 | .77 | 178 | 178 | 320 | 292 |

STATION C-6 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M² | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 21 MARCH | 92 | 2.0 | 3612 | 344 | 366 | 194 | 0 | 2591 | 2000 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2086 | 151 | 430 | 43 | 0 | 1251 | 957 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1957 | 301 | 194 | 86 | 0 | 2030 | 1355 | -- | -- | -- | -- | -- | -- | -- | -- |
| 25 APR | 98 | 3.0 | 3440 | 43 | 387 | 172 | 0 | 1548 | 1127 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4730 | 43 | 301 | 215 | 0 | 1681 | 1324 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3096 | 129 | 473 | 43 | 43 | 1484 | 1066 | -- | -- | -- | -- | -- | -- | -- | -- |
| 1 JUNE | 100 | 6.8 | 2451 | 43 | 215 | 65 | 0 | 2559 | 2165 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2000 | 108 | 280 | 151 | 0 | 2352 | 1929 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 2301 | 194 | 237 | 108 | 0 | 3133 | 2724 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C-7 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 22 MARCH | 52 | 1.9 | 3290 | 473 | 1226 | 237 | 0 | 2118 | 1591 | 3.37 | 2.93 | 1.07 | 1.17 | 139 | 131 | 697 | 611 |
| | | | 2645 | 1226 | 688 | 301 | 0 | 3470 | 2625 | 3.73 | 3.60 | 1.17 | 1.87 | 134 | 146 | 323 | 272 |
| | | | 5053 | 538 | 581 | 22 | 0 | 3730 | 2625 | 3.13 | 3.10 | 1.63 | 1.17 | 134 | 142 | 365 | 331 |
| 25 APR | 55 | 3.0 | 10277 | 172 | 2150 | 0 | 0 | 4072 | 2890 | 1.27 | 2.00 | .17 | .70 | 139 | 142 | 107 | 84 |
| | | | 10578 | 129 | 860 | 43 | 0 | 3801 | 3105 | 1.67 | 1.57 | .40 | .83 | 141 | 149 | 165 | 152 |
| | | | 11739 | 129 | 3440 | 301 | 0 | 6390 | 4451 | 1.60 | 1.47 | .50 | .47 | 122 | 137 | 55 | 39 |
| 16 MAY | 54 | 4.5 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.10 | 2.83 | .73 | 1.10 | 140 | 138 | 150 | 130 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.17 | 2.90 | .73 | 1.13 | 148 | 151 | 45 | 31 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.20 | 2.53 | .77 | .87 | 143 | 148 | 34 | 21 |
| 1 JUNE | 56 | 10.0 | 4300 | 215 | 1290 | 22 | 0 | 5392 | 4504 | 2.03 | 2.87 | .97 | 1.07 | 160 | 182 | 80 | 40 |
| | | | 3548 | 581 | 946 | 129 | 0 | 5556 | 4451 | 1.73 | 2.57 | .73 | .73 | 174 | 164 | 100 | 79 |
| | | | 3935 | 215 | 1247 | 129 | 0 | 4595 | 3769 | 1.80 | 2.80 | .93 | 1.07 | 173 | 179 | 147 | 101 |

STATION C*-1 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 4 APR | 39 | 1.6 | 6515 | 2086 | 946 | 1462 | 0 | 7830 | 5902 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6966 | 2322 | 2731 | 1785 | 0 | 9221 | 6721 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6880 | 1269 | 790 | 1032 | 0 | 8895 | 6996 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 JUNE | 38 | 5.5 | 7590 | 1333 | 3204 | 2066 | 0 | 11715 | 8940 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6063 | 1161 | 1828 | 2301 | 0 | 9630 | 7680 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6644 | 1742 | 2107 | 2150 | 0 | 10271 | 8093 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION C*-2 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 4 APR | 96 | 1.9 | 5483 | 667 | 172 | 237 | 0 | 4728 | 3945 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4655 | 1290 | 215 | 452 | 0 | 4967 | 4057 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 3247 | 602 | 129 | 430 | 0 | 2984 | 2520 | -- | -- | -- | -- | -- | -- | -- | -- |
| 6 JUNE | 100 | 11.0 | 5999 | 667 | 86 | 516 | 0 | 6742 | 5964 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5375 | 1011 | 151 | 473 | 0 | 6751 | 5359 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5504 | 172 | 129 | 344 | 0 | 6398 | 5756 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION D-1 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 4 APR | 30 | 1.9 | 7525 | 1720 | 1548 | 0 | 0 | 3801 | 2455 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6816 | 624 | 1333 | 43 | 0 | 3496 | 2279 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7482 | 796 | 1720 | 108 | 22 | 4460 | 2801 | -- | -- | -- | -- | -- | -- | -- | -- |
| 29 APR | 31 | 3.5 | 2774 | 602 | 1118 | 43 | 0 | 3098 | 2135 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5956 | 194 | 409 | 22 | 0 | 3221 | 2559 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4816 | 516 | 860 | 0 | 0 | 3801 | 2750 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 JUNE | 30 | 6.0 | 4586 | 688 | 1247 | 0 | 0 | 6106 | 4784 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5225 | 1032 | 1075 | 65 | 0 | 5515 | 4511 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4515 | 774 | 1720 | 0 | 0 | 6214 | 4042 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION D-2 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L DRY |  | ASH FREE |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M² |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 4 APR | 98 | 1.8 | 3870 | 1484 | 452 | 344 | 0 | 3631 | 2898 | 2.20 | 3.27 | 1.00 | 1.37 | 169 | 169 | 179 | 163 |
|  |  |  | 2580 | 916 | 667 | 86 | 0 | 2756 | 2187 | 2.83 | 2.40 | .93 | .73 | 170 | 170 | 112 | 101 |
|  |  |  | 4515 | 1204 | 731 | 65 | 0 | 4534 | 3462 | 2.37 | 2.43 | .93 | .83 | 162 | 168 | 222 | 203 |
| 29 APR | 109 | 2.9 | 3720 | 495 | 323 | 108 | 0 | 3700 | 3079 | 2.27 | 2.37 | .63 | .93 | 175 | 176 | 929 | 843 |
|  |  |  | 3053 | 516 | 452 | 86 | 0 | 3251 | 2649 | 2.50 | 2.47 | .83 | .67 | 172 | 177 | 1141 | 1047 |
|  |  |  | 2881 | 581 | 452 | 129 | 0 | 3305 | 2703 | 2.57 | 2.40 | .67 | .40 | 179 | 171 | 909 | 833 |
| 17 MAY | 99 | 3.4 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.27 | 2.97 | .70 | 1.00 | 141 | 158 | 149 | 127 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.10 | 3.27 | .83 | .87 | 144 | 158 | 48 | 39 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.27 | 2.70 | .97 | 1.20 | 136 | 142 | 40 | 25 |
| 4 JUNE | 104 | 4.5 | 3720 | 366 | 344 | 86 | 0 | 3861 | 3328 | 1.87 | 2.30 | 1.27 | 1.23 | 172 | 176 | 113 | 96 |
|  |  |  | 3505 | 194 | 409 | 151 | 0 | 4358 | 3788 | 1.97 | 2.67 | .93 | 1.20 | 178 | 178 | 390 | 354 |
|  |  |  | 4021 | 172 | 108 | 86 | 0 | 4251 | 3685 | 2.00 | 2.37 | .90 | 1.10 | 164 | 174 | 323 | 283 |

STATION D-3 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L DRY |  | ASH FREE |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M² |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 5 APR | 174 | 1.3 | 1935 | 237 | 43 | 65 | 0 | 1428 | 1219 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 1720 | 151 | 22 | 22 | 0 | 1502 | 1318 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 1763 | 194 | 43 | 65 | 0 | 1484 | 1245 | -- | -- | -- | -- | -- | -- | -- | -- |
| 29 APR | 175 | 3.2 | 1742 | 301 | 43 | 43 | 0 | 1245 | 1066 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 1849 | 172 | 129 | 108 | 0 | 1380 | 1159 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 1785 | 172 | 0 | 65 | 0 | 1223 | 1058 | -- | -- | -- | -- | -- | -- | -- | -- |
| 4 JUNE | 174 | 4.0 | 989 | 22 | 22 | 22 | 0 | 669 | 565 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 1075 | 22 | 65 | 43 | 0 | 1135 | 987 | -- | -- | -- | -- | -- | -- | -- | -- |
|  |  |  | 1699 | 86 | 0 | 0 | 0 | 1619 | 1430 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION D-4 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L DRY |  | ASH FREE |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M² |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 5 APR | 134 | 1.5 | 2344 | 151 | 43 | 0 | 0 | 1245 | 1112 | 1.73 | 1.40 | .80 | .60 | 179 | 172 | 522 | 476 |
|  |  |  | 1785 | 1441 | 108 | 22 | 0 | 1924 | 1148 | 1.73 | 1.40 | .73 | .47 | 170 | 172 | 485 | 451 |
|  |  |  | 2451 | 430 | 151 | 22 | 0 | 1877 | 1481 | 1.73 | 1.50 | .73 | .67 | 163 | 176 | 343 | 316 |
| 29 APR | 134 | 2.9 | 2150 | 43 | 108 | 0 | 0 | 1148 | 946 | 1.43 | 1.67 | .57 | .53 | 140 | 172 | 804 | 746 |
|  |  |  | 5418 | 731 | 387 | 258 | 0 | 1359 | 1150 | 1.30 | 1.57 | .47 | .60 | 194 | 183 | 565 | 522 |
|  |  |  | 2516 | 215 | 22 | 43 | 0 | 1898 | 1630 | 1.33 | 1.53 | .67 | .53 | 158 | 139 | 838 | 751 |
| 17 MAY | 130 | 3.4 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.03 | 3.27 | .93 | 1.43 | 138 | 171 | 215 | 199 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.63 | 1.93 | .63 | .63 | 157 | 163 | 74 | 51 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.43 | 4.87 | .47 | 1.40 | 159 | 171 | 283 | 266 |
| 4 JUNE | 129 | 4.9 | 2516 | 215 | 22 | 43 | 0 | 2434 | 2064 | 1.43 | 2.13 | .50 | .80 | 160 | 175 | 553 | 471 |
|  |  |  | 1312 | 409 | 65 | 86 | 0 | 1647 | 1393 | 1.57 | 1.93 | .50 | .77 | 169 | 185 | 379 | 339 |
|  |  |  | 344 | 65 | 43 | 0 | 0 | 151 | 129 | 1.57 | 1.80 | .67 | .77 | 172 | 182 | 560 | 518 |

STATION D-5 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER |  |  |  |  | WT OF BENTH ORGAN MG/M² |  | SUSPENDED PARTICULATE MATTER MG/L DRY |  | ASH FREE |  | FILTERABLE RESIDUE ON EVAPORATION MG/L |  | ZOOPLK MG/M² |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | 0-25 | >25 | 0-25 | >25 | 0-25 | >25 | DRY | ASH FREE |
| 5 APR | 123 | 2.9 | 4085 | 366 | 194 | 65 | 0 | 2387 | 1967 | 1.63 | 1.50 | .63 | .60 | 150 | 140 | 409 | 344 |
|  |  |  | 4042 | 473 | 65 | 22 | 0 | 2739 | 2283 | 1.77 | 1.50 | .83 | .73 | 144 | 167 | 211 | 178 |
|  |  |  | 3612 | 323 | 129 | 151 | 0 | 2359 | 1941 | 1.80 | 1.50 | .67 | .63 | 142 | 142 | 270 | 257 |
| 28 APR | 122 | 3.0 | 2967 | 43 | 301 | 0 | 0 | 2328 | 1920 | 1.93 | 1.73 | .87 | .73 | 136 | 151 | 587 | 527 |
|  |  |  | 3096 | 108 | 86 | 65 | 0 | 1768 | 1488 | 2.10 | 1.67 | 1.03 | .63 | 146 | 150 | 639 | 589 |
|  |  |  | 3677 | 516 | 43 | 43 | 0 | 2799 | 2395 | 1.50 | 1.57 | .57 | .77 | 152 | 149 | 488 | 438 |
| 17 MAY | 119 | 3.4 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.50 | 1.93 | .73 | .93 | 143 | 151 | 294 | 270 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.43 | 2.33 | .53 | 1.07 | 158 | 140 | 85 | 67 |
|  |  |  | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.43 | 2.13 | .67 | .87 | 146 | 148 | 177 | 159 |
| 1 JUNE | 120 | 5.0 | 5031 | 366 | 344 | 22 | 0 | 4341 | 3642 | 1.37 | 1.90 | .73 | .77 | 165 | 183 | 417 | 372 |
|  |  |  | 4214 | 151 | 151 | 0 | 0 | 3580 | 3102 | 1.50 | 1.87 | .67 | 1.13 | 174 | 180 | 412 | 377 |
|  |  |  | 2129 | 0 | 43 | 0 | 0 | 1898 | 1623 | 1.50 | 1.80 | .70 | 1.00 | 176 | 181 | 404 | 366 |

STATION D-6 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 5 APR | 34 | 3.1 | 20490 | 2129 | 10170 | 323 | 0 | 13433 | 5028 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 15074 | 2021 | 3577 | 280 | 0 | 10591 | 6889 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 12900 | 3698 | 2215 | 194 | 0 | 8712 | 6618 | -- | -- | -- | -- | -- | -- | -- | -- |
| 28 APR | 34 | 4.2 | 11718 | 452 | 2903 | 258 | 0 | 9226 | 6570 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 13266 | 1269 | 3483 | 258 | 43 | 10486 | 7759 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 14921 | 516 | 1527 | 151 | 0 | 8723 | 6925 | -- | -- | -- | -- | -- | -- | -- | -- |
| 2 JUNE | 33 | 6.7 | 8637 | 108 | 3892 | 22 | 0 | 8858 | 7056 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10492 | 237 | 258 | 65 | 0 | 7617 | 6805 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 11825 | 559 | 774 | 43 | 0 | 7048 | 6749 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION E-1 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 7 APR | 48 | 2.2 | 9288 | 1441 | 3655 | 430 | 22 | 5446 | 3481 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 14255 | 2838 | 2172 | 559 | 0 | 6007 | 3896 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9718 | 774 | 151 | 624 | 0 | 3595 | 2909 | -- | -- | -- | -- | -- | -- | -- | -- |
| 30 APR | 39 | 3.3 | 10922 | 559 | 2236 | 559 | 0 | 2610 | 1939 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9116 | 903 | 4644 | 387 | 86 | 3066 | 1681 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 6966 | 430 | 1677 | 559 | 0 | 1703 | 1247 | -- | -- | -- | -- | -- | -- | -- | -- |
| 3 JUNE | 42 | 6.5 | 5332 | 516 | 237 | 22 | 0 | 4870 | 4343 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 9525 | 839 | 2430 | 237 | 0 | 7784 | 6201 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4429 | 129 | 839 | 43 | 0 | 5775 | 4971 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION E-2 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 6 APR | 204 | 2.3 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.27 | 1.73 | .80 | .50 | 166 | 176 | -1 | -1 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.17 | 1.53 | .73 | .47 | 137 | 143 | 107 | 87 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 2.17 | 1.70 | .73 | .57 | 168 | 174 | 151 | 130 |
| 30 APR | 201 | 2.9 | 2795 | 301 | 85 | 86 | 0 | 929 | 563 | 1.37 | 1.57 | .50 | .50 | 163 | 150 | 652 | 634 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.53 | 1.70 | .37 | .47 | 162 | 158 | 741 | 711 |
| | | | 258 | 86 | 0 | 0 | 0 | 60 | 43 | 1.50 | 1.87 | .47 | .53 | 153 | 153 | 677 | 645 |
| 18 MAY | 200 | 3.2 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.27 | 2.13 | .43 | .87 | 168 | 154 | 223 | 190 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.37 | 1.57 | .33 | .73 | 154 | 158 | 398 | 361 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.20 | 1.37 | .47 | .37 | 168 | 160 | 150 | 127 |
| 3 JUNE | 201 | 4.9 | 1570 | 86 | 65 | 0 | 0 | 978 | 832 | 1.80 | 2.10 | .80 | .87 | 165 | 162 | -1 | -1 |
| | | | 581 | 22 | 65 | 22 | 0 | 353 | 286 | 1.97 | 1.80 | .83 | .70 | 168 | 164 | -1 | -1 |
| | | | 1118 | 129 | 43 | 22 | 0 | 856 | 737 | 1.73 | 1.83 | .77 | .73 | 162 | 164 | 1178 | 1064 |

STATION E-3 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER | | | | | WT OF BENTH ORGAN MG/M$^2$ | | SUSPENDED PARTICULATE MATTER MG/L | | | | FILTERABLE RESIDUE ON EVAPORATION MG/L | | ZOOPLK MG/M$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMPH | OLIGO | SPHAE | TEND | OTH | DRY | ASH FREE | DRY 0-25 | DRY >25 | ASH FREE 0-25 | ASH FREE >25 | 0-25 | >25 | DRY | ASH FREE |
| 6 APR | 269 | 3.1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .97 | .73 | .53 | .43 | 145 | 160 | 584 | 540 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .97 | 1.23 | .60 | .70 | 153 | 152 | 690 | 646 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.37 | 1.03 | .77 | .57 | 152 | 148 | 476 | 433 |
| 30 APR | 271 | 3.2 | 731 | 215 | 0 | 0 | 0 | 211 | 163 | .60 | .53 | .27 | .30 | 150 | 142 | 274 | 261 |
| | | | 860 | 0 | 0 | 0 | 0 | 151 | 103 | .60 | .63 | .43 | .27 | 146 | 146 | 335 | 317 |
| | | | 1935 | 172 | 0 | 0 | 43 | 357 | 241 | .60 | .50 | .37 | .27 | 138 | 151 | 527 | 490 |
| 18 MAY | 268 | 3.8 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.10 | 1.00 | .43 | .33 | 166 | 169 | 1153 | 1080 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.00 | 1.00 | .57 | .57 | 167 | 172 | 1281 | 1153 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | .93 | 1.00 | .43 | .60 | 178 | 189 | 995 | 950 |
| 3 JUNE | 263 | 3.8 | 258 | 0 | 0 | 0 | 0 | 129 | 108 | 1.17 | 1.80 | .70 | 1.07 | 172 | 180 | 363 | 327 |
| | | | 344 | 22 | 65 | 0 | 0 | 172 | 129 | .90 | 1.50 | .50 | 1.00 | 174 | 170 | 405 | 377 |
| | | | 452 | 86 | 0 | 0 | 0 | 273 | 239 | 1.10 | 1.00 | .47 | .47 | 179 | 171 | 475 | 446 |

STATION E-4 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 APR | 241 | 2.9 | 882 | 129 | 65 | 0 | 0 | 262 | 213 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 698 | 108 | 43 | 43 | 0 | 241 | 196 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |
| 30 APR | 211 | 3.0 | 1247 | 0 | 0 | 0 | 0 | 353 | 206 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 516 | 0 | 0 | 0 | 0 | 69 | 26 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 1720 | 86 | 0 | 0 | 0 | 310 | 189 | -- | -- | -- | -- | -- | -- | -- | -- |
| 3 JUNE | 224 | 3.9 | 516 | 0 | 151 | 0 | 0 | 318 | 245 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 624 | 22 | 65 | 43 | 0 | 353 | 269 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 430 | 22 | 129 | 22 | 0 | 157 | 129 | -- | -- | -- | -- | -- | -- | -- | -- |

STATION E-5 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 APR | 173 | 2.2 | 2838 | 237 | 559 | 22 | 0 | 1649 | 1275 | 1.20 | .87 | .63 | .47 | 147 | 164 | 61 | 44 |
| | | | 2279 | 129 | 258 | 0 | 0 | 1477 | 1247 | 1.00 | 1.17 | .47 | .43 | 154 | 164 | 211 | 187 |
| | | | 2043 | 581 | 387 | 43 | 0 | 1234 | 980 | 1.30 | 1.07 | .60 | .47 | 152 | 156 | 160 | 141 |
| 30 APR | 174 | 2.9 | 3556 | 0 | 215 | 0 | 0 | 993 | 770 | 1.03 | .93 | .50 | .37 | 158 | 162 | 442 | 406 |
| | | | 3526 | 86 | 430 | 0 | 0 | 890 | 701 | .90 | 1.13 | .33 | .50 | 142 | 150 | 355 | 314 |
| | | | 2881 | 0 | 43 | 0 | 0 | 757 | 529 | 1.00 | 1.00 | .53 | .37 | 134 | 150 | 485 | 456 |
| 18 MAY | 174 | 3.5 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.20 | 1.17 | .60 | .53 | 179 | 171 | 745 | 702 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.10 | 1.20 | .50 | .43 | 180 | 172 | 804 | 764 |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1.07 | 1.33 | .43 | .80 | 184 | 187 | 783 | 738 |
| 2 JUNE | 186 | 3.6 | 1290 | 86 | 172 | 0 | 0 | 1021 | 866 | 1.47 | 1.90 | .70 | .93 | 180 | 185 | 491 | 442 |
| | | | 1290 | 151 | 0 | 43 | 0 | 860 | 750 | 1.50 | 1.37 | .57 | .63 | 192 | 181 | 562 | 517 |
| | | | 538 | 65 | 22 | 0 | 0 | 381 | 329 | 1.70 | 1.00 | .83 | .60 | 202 | 176 | 575 | 517 |

STATION E-6 1966

| DATE | DPTH METR | SFC TEM C | BENTHIC ORGANISMS PER SQUARE METER AMPH | OLIGO | SPHAE | TEND | OTH | WT OF BENTH ORGAN MG/M² DRY | ASH FREE | SUSPENDED PARTICULATE MATTER MG/L DRY 0-25 | >25 | ASH FREE 0-25 | >25 | FILTERABLE RESIDUE ON EVAPORATION MG/L 0-25 | >25 | ZOOPLK MG/M² DRY | ASH FREE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 APR | 35 | 1.5 | 4257 | 1355 | 5375 | 129 | 0 | 7076 | 3969 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 7310 | 3397 | 6450 | 194 | 0 | 7643 | 4618 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 5461 | 516 | 19737 | 882 | 22 | 13008 | 4412 | -- | -- | -- | -- | -- | -- | -- | -- |
| 29 APR | 34 | 3.3 | 14964 | 86 | 6622 | 344 | 0 | 6437 | 3737 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 10277 | 903 | [illegible] | 86 | 43 | 4962 | 2928 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 16383 | 344 | 15050 | 430 | 0 | 10535 | 4223 | -- | -- | -- | -- | -- | -- | -- | -- |
| 2 JUNE | 35 | 7.0 | 6902 | 194 | 464 | 0 | 22 | 8867 | 7512 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | 4558 | 65 | 301 | 0 | 0 | 8250 | 6695 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -- | -- | -- | -- | -- | -- | -- | -- |

# GEOLOGICAL STUDIES OF LAKE MICHIGAN

Jack L. Hough

## INTRODUCTION

The geological studies have included the topography of the lake basin, as a basis for various other phases of the program. investigation of the bedrock framework of the basin; the running of sub-bottom profiles with a continuous seismic profiler; the mapping of distribution of bottom-surface sediments; core-sampling of the bottom to investigate vertical distribution of sediment types; dating of organic remains in the sediment by the radiocarbon method; and detailed studies in a small area (the Manitou Passage) of bottom sediments in relation to their physical environment.

These studies, and the inter-relations between them, are reported in the following pages.

## TOPOGRAPHIC STUDIES

The purpose of these studies was to provide topographic maps for use in most of the other phases of the work. The published navigation charts of the U.S. Lake Survey contain only a small fraction of the survey data and, with the exception of the small-scale general chart of the Great Lakes, they show no contour lines. In this study, all of the available published charts, and copies of the Lake Survey unpublished field sheets, were used to construct contour maps of a large part of the Lake Michigan basin. During most of the period of the Coherent Area project, these contour maps were maintained as work sheets. Additional depth-data, taken from a considerable portion of the echograms run by the Division's ships on all of their crossings of the lake, have been plotted on the work sheets and the contours have been adjusted from time to time.

### TOPOGRAPHIC ATLAS

A "Topographic Atlas" of Lake Michigan has been established, with maps being prepared on three scales, as follows:

I. Lake Michigan, South of 45° N. Lat. Scale 1:500,000. Size of map, 25 x 31 inches. Base, U.S. Lake Survey Chart No. 7. Contours were transferred to this map from the larger scale maps of Series II. (This is the base map of Figure 2.)

II. Section maps. Scale 1:120,000. Size of map, 29 x 52 inches. Base, U.S. Lake Survey unpublished field data sheets. Additional data taken from Great Lakes Research Division echograms. Seven section sheets will cover entire lake; four are completed. Remaining three delayed, until results of new surveys in the north end of the lake, being made by the U. S. Lake Survey, are available. The completed sheets are as follows:

Sheet No. 1—41°30'-42°15' N. Lat.
Sheet No. 2—42°15'-43°00' N. Lat.
Sheet No. 3—43°00'-43°45' N. Lat.
Sheet No. 4—43°45'-44°30' N. Lat.

(These are the base maps of Figures 1-4 of "The surficial bottom sediments of Lake Michigan" by J. C. Ayers, in this report.)

III. 10-minute quadrangles. Scale 1:31,680 (1 inch = 0.5 mile). Size of maps, 18 x 26 inches. Base: enlargement from Series II, Section Maps. The purpose of constructing these maps is to portray selected areas of special interest. In each such area the U. S. Lake Survey sounding data have been used and detailed topographic surveys have been run by Great Lakes Research Division vessels; the resulting data have been contoured. These maps are approximately at the horizontal scale of the echogram used on the Research Vessel INLAND SEAS when running at full speed, so that they are useful in field service for locating and guiding detailed work such as dredging and bottom sampling, and they have been used in guiding the diving operations of a research submarine.

The areas covered by 10-min. quadrangles are as follows:

| | | |
|---|---|---|
| 42°55'-43°05'N. | 86°40'-86°50'W. | (So. Lake Chippewa sill) |
| 43°00'-43°10'N. | 87°10'-87°20'W. | |
| 43°00'-43°10'N. | 87°20'-87°30'W. | (Cliffs E. of Milwaukee-I) |
| 43°00'-43°10'N. | 87°30'-87°40'W. | (Cliffs E. of Milwaukee-II) |
| 43°10'-43°20'N. | 87°30'-87°40'W. | (Cliffs E. of Milwaukee-III) |
| 43°15'-43°25'N. | 87°05'-87°15'W. | (Midlake high) |
| 43°30'-43°40'N. | 86'50'-87°00'W. | (N. E. corner, midlake high) |

## MODEL OF LAKE MICHIGAN

A three-dimensional model of Lake Michigan is under construction on a horizontal scale of 1:120,000 and a vertical scale of 1 in. to 100 ft. It is being built in seven sections, each one coinciding with the area covered by one of the Section Maps of the "Topographic Atlas."

Four [illegible] have been completed, [illegible]:

Section [illegible], [illegible] N. Lat.
Section [illegible], [illegible] N. Lat.
Section [illegible], [illegible] N. Lat.
Section [illegible], [illegible] N. Lat.

A photograph of the [illegible] portion of the model is shown in Fig. [illegible]. This model has been useful as an aid in visualizing [illegible] relationships between the topography and bedrock structure, sediment distribution, and other aspects of the lake, [illegible]. It has been helpful in [illegible] of water in the lake, [illegible] a water-filled [illegible] the [illegible] sand.

FIG. [illegible]. [illegible]

## [illegible]

The purpose of this [illegible] the [illegible] of the [illegible], [illegible] structure [illegible] the effect [illegible] the topography of the basin. [illegible], [illegible], [illegible].

The bedrock formations on the land surrounding the basin of Lake Michigan are fairly well known, from their outcrops and from numerous well logs. Before this study was begun, the bedrock underlying the lake was practically unknown, except for guesses that could be made by projecting formation outcrop zones offshore.

The problem of the distribution of bedrock formations under the lake is of particular interest because there is an unconformity in the Paleozoic sedimentary rock column in the region. The entire Devonian section of rocks which is present at the north end of the lake, between the Silurian rocks of the north shore and Lower Mississippian rocks of the Lower Peninsula of Michigan, is missing at the south end of the lake, where the Antrim Shale (Mississippian) lies directly on the Niagaren Dolomite (Silurian). Further, the topography of some parts of the basin can be correlated with the expected occurrences of bedrock types (ridges correlating with harder rocks, basins correlating with soft rocks); but in other parts of the basin there seems to be no such correlation possible.

Bedrock outcrops on the bottom of the lake were found by dredging, from a surface vessel, on many steep to vertical cliffs. These were located by study of the topographic maps and by making crossings of likely areas to obtain echogram profiles. When a steep slope was found, a buoy was placed at its top and a large dredge was hauled up the slope. Practically all of the known vertical cliffs and especially steep slopes of the lake have been dredged, and samples of bedrock have been obtained from several of them.

## RESULTS

The occurrences of identified bedrock formations on the lake bottom are shown on the geologic map (Fig. 2) and are discussed in the following paragraphs.

Silurian rocks, mainly the Niagaran Dolomite, occur along the western shore of the lake, and are present in some of the reefs in shallow water adjacent to the shore. The Silurian Burnt Bluff limestone formation was found in a cliff 8 miles ESE of Rawley Point, which is 11 miles NE of Manitowoc, Wis.

Traverse Group limestone (Devonian), which occurs along (or under) the shore of the southern peninsula of Michigan from Frankfort northeastward to Petoskey, was found on the lake bottom at several points, in an area of vertical cliffs which lies about 20 miles east of the western shore in the latitudes of Port Washington to Milwaukee, Wis., and at one additional point 36 miles east of Milwaukee.

A sandy phase of the Coldwater Shale (Mississippian), which underlies the Lower Peninsula of Michigan and runs off the eastern shore of the lake in a zone from Big Sable Point to Little Sable Point (neart Ludington), was found at three points on the lake bottom west of Little Sable Point. One of these is on a vertical cliff on the eastern rim of the lake basin. The others are on vertical

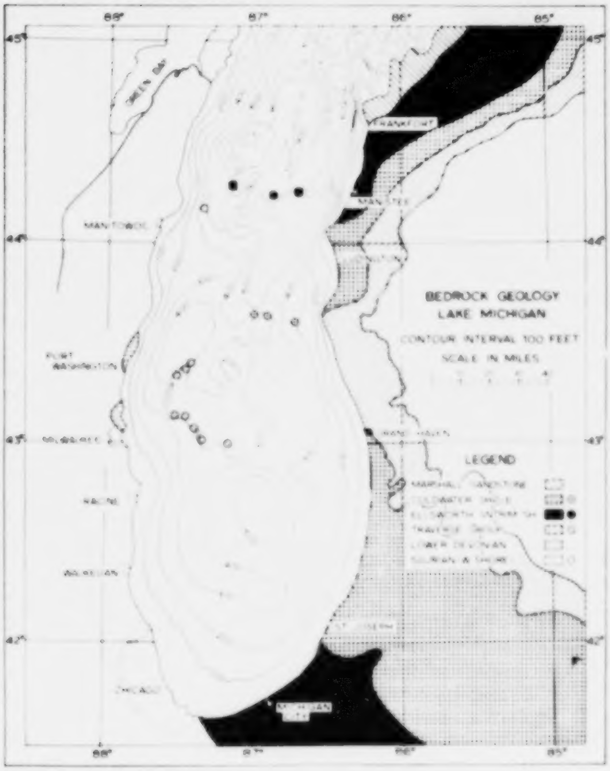

88°
87°
86°
85°
45°
44°
43°
42°
GREEN BAY
FRANKFORT
MANISTEE
MANITOWOC
BEDROCK GEOLOGY
LAKE MICHIGAN
CONTOUR INTERVAL 100 FEET
SCALE IN MILES
PORT WASHINGTON
GRAND HAVEN
MILWAUKEE
LEGEND
MARSHALL SANDSTONE
COLDWATER SHALE
ELLSWORTH ANTRIM SH
TRAVERSE GROUP
LOWER DEVONIAN
SILURIAN & SHORE
RACINE
WAUKEGAN
ST. JOSEPH
CHICAGO
MICHIGAN CITY

FIG. 2. Bedrock geology of Lake Michigan, showing locations of rock-dredge samples.

cliffs at the northeastern margin of a large topographically high area of the mid-lake region, and separated from the first by a deep channel. All, however, are in the trend of the outcrop zone of the Coldwater Shale, projected offshore. From this information, the Coldwater Shale would be expected to occur at the shallowest part of the mid-lake high area, a few miles farther southwest in the projected outcrop zone, but dredging of that area has failed to yield any bedrock.

The Antrim Shale (lower Mississippian or Upper Devonian) is mapped as underlying the shore at the south end of the lake. The Antrim Shale and the next overlying formation, the Ellsworth Shale, are mapped as underlying the eastern shore of the lake from near Frankfort southward to near Big Sable Point. If this outcrop zone of these formations is projected offshore to the southwest, it passes through a lake-bottom trough lying just north of, and parallel with, the outcrop zone of the overlying Coldwater Shale. This trough extends southwestward to pass to the west of the mid-lake high area, and then turns southward between it and the western shore. The Antrim-Ellsworth zone cannot be projected to the west of the mid-lake high area, however, because it must be placed between the Coldwater and Traverse outcrop zones. The Antrim-Ellsworth zone therefore is considered as lying between the shallowest part and the cliffs of the western margin of the mid-lake high area.

Samples of Antrim Shale and Ellsworth Shale were taken from the lake bottom at a point 18 miles west of Manistee, Mich. This is approximately at the northwestern edge of the projected outcrop zone of the combined Antrim and Ellsworth, and thus places the Ellsworth a little farther west than was expected.

Ellsworth Shale was found on the lake bottom at two additional points, one 27 miles west of Manistee and the other 41 miles wert of Manistee, or 19 miles east of the western shore of the lake. Both of these points are well to the west of the projected position of the outcrop zone, and these occurrences therefore pose a problem.

The bottom topography in the north-central part of the lake (between 44° and 45° N. Lat.), which included the Antrim and Ellsworth localities, has features of interest which may be related to characteristics of the bedrock. There are several ridges which trend about N. 35° E, roughly parallel with the bedrock formation outcrop zones of the eastern shore. The ridges are, however, discontinuous, and a part of the area could be characterized as having a jumbled topography with randomly distributed hills and basins.

Considering the displacement of rocks and the irregular topography, this area may have under gone some structural readjustments. It is proposed, therefore, that the explanation given for the Mackinac Breccia and tilted blocks of the Straits of Mackinac area may be used to explain the features of the north central part of the lake. This is, that solution of salt from the Salina Formation (Siluvian), which lies above the Niagaran Dolomite, has allowed the overlying rocks to fracture and settle to structurally lower positions (Landes, Ehlers, and Stanley 1945, pp. 143-145).

Because of the small amount of information available on the bedrock occurrences under the lake, and the complicated nature of the topography, no attempt has been made to draw formation boundaries on the lake area of the geologic map.

## SUB-BOTTOM PROFILES

Continuous seismic profiles were made on a number of crossings of the lake. The equipment used was an early model of a "sparker," which performed well during only a part of the surveys. For the present report, only the better records have been processed and illustrated. The locations of these are shown in Fig. 3, and the cross sections are given in Figs. 4-12.

Detailed description and interpretation of these profiles is being carried out in a continuing study of the geology of the central part of Lake Michigan.

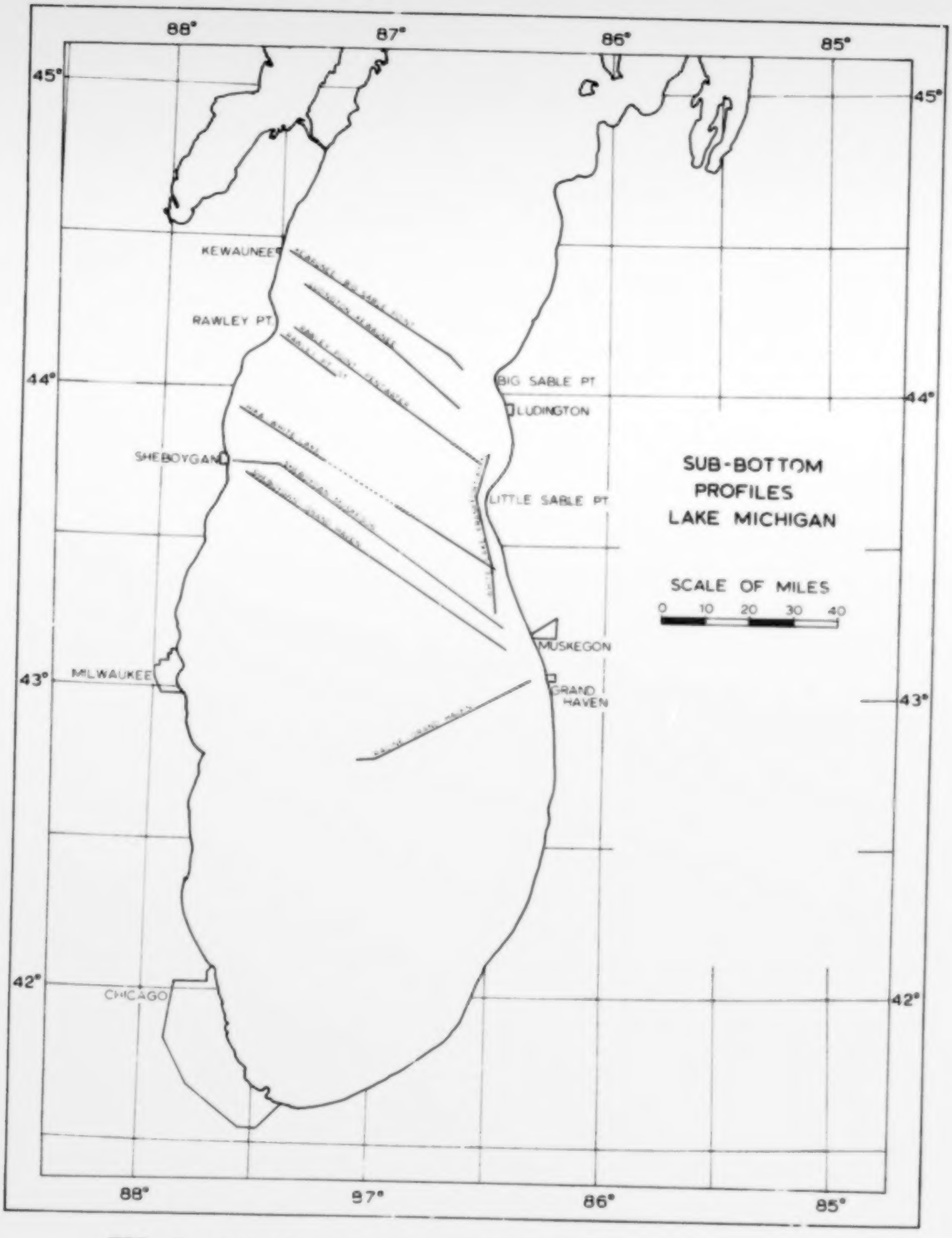

88°
87°
86°
85°
45°
44°
43°
42°
KEWAUNEE
RAWLEY PT.
SHEBOYGAN
MILWAUKEE
CHICAGO
BIG SABLE PT
LUDINGTON
LITTLE SABLE PT
MUSKEGON
GRAND HAVEN
SUB-BOTTOM PROFILES LAKE MICHIGAN
SCALE OF MILES
0
10
20
30
40

FIG. 3. Locations of selected sub-bottom profiles.

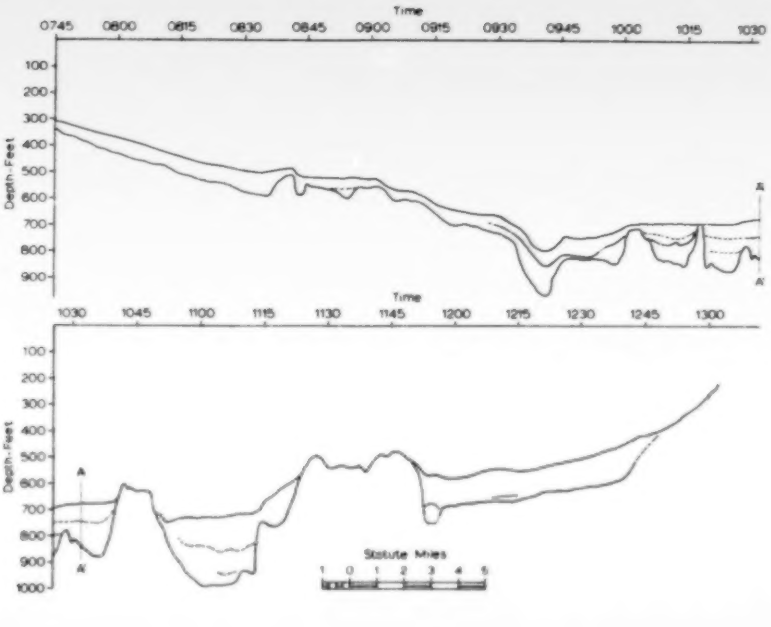


FIG. 4. Profile, Kewaunee - Big Sable Point.

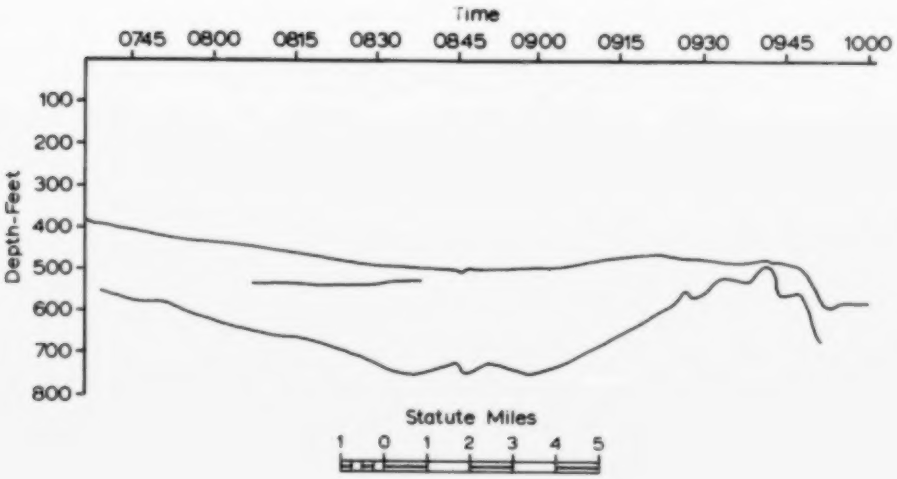


FIG. 5. Profile, Ludington - Kewaunee.

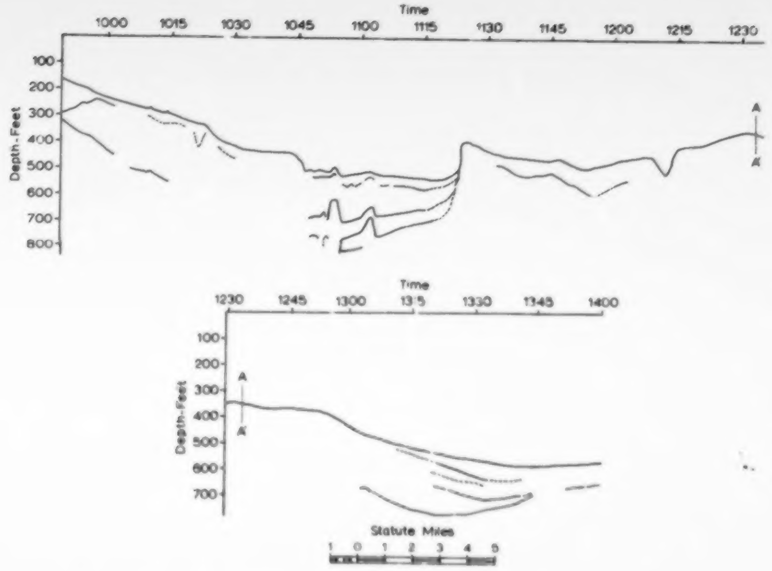


FIG. 6. Profile, Rawley Point - Pentwater.

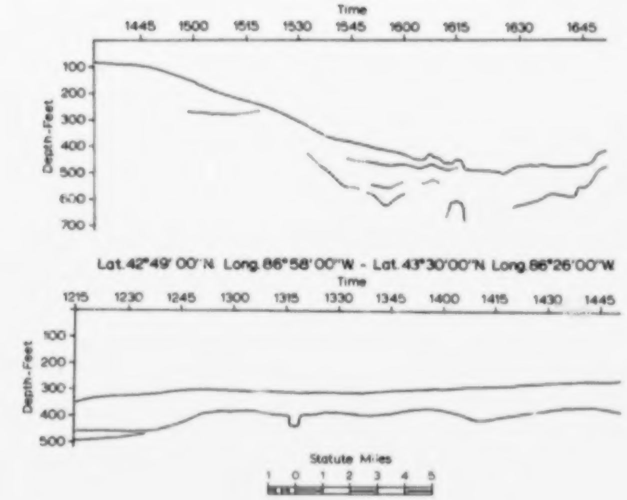


FIG. 7. Profile, Rawley Point - 20 miles S.E. Rawley Point.

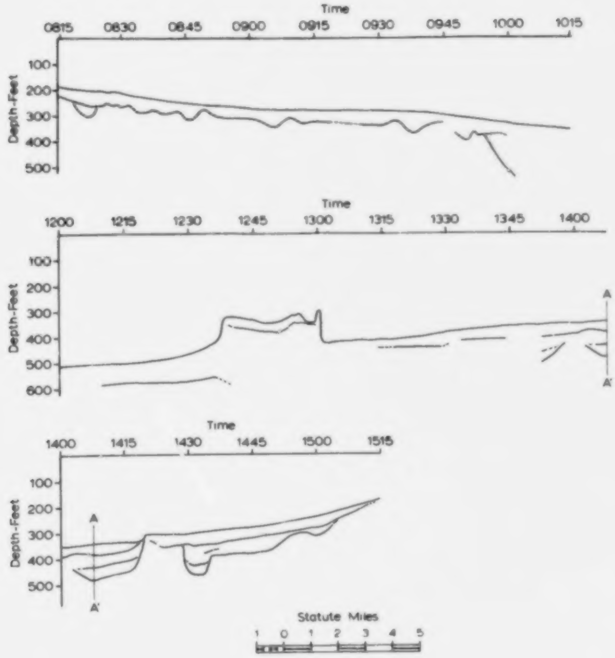


FIG. 8. Profile, Hika - White Lake.

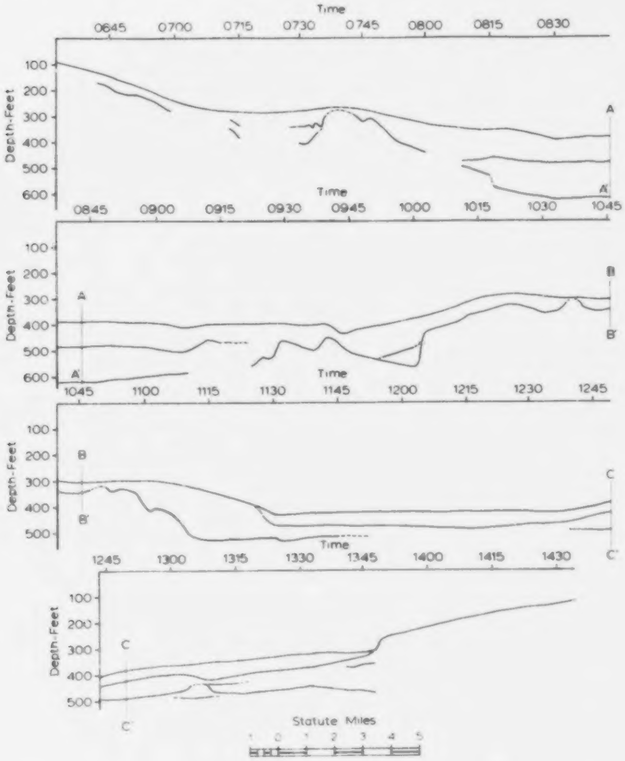


FIG. 9. Profile, Sheboygan - Muskegon.

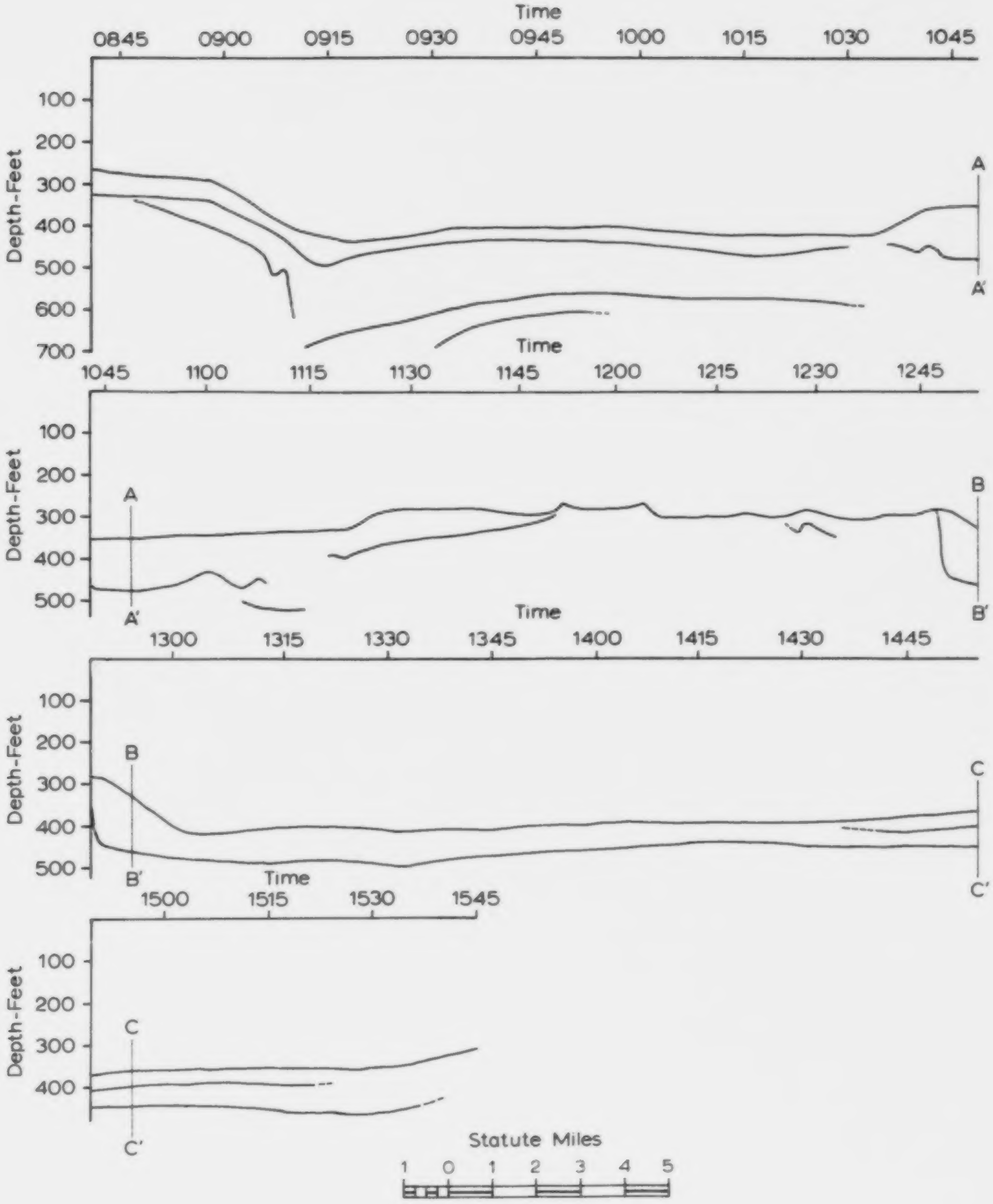


FIG. 10. Profile, Sheboygan - Grand Haven.

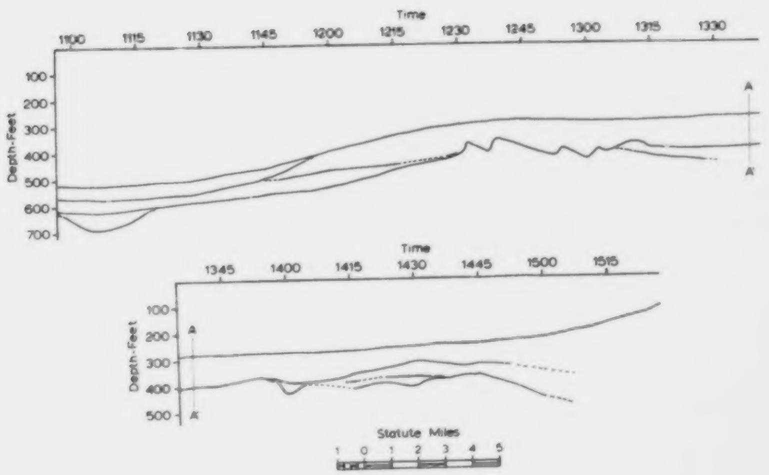


FIG. 11. Profile, Racine - Grand Haven.

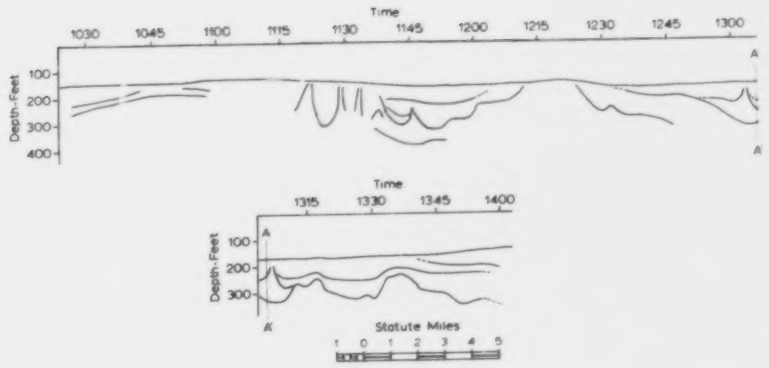


FIG. 12. Profile, White Lake - Frankfort.

several of the profiles show two or three sub-bottom interfaces. The deepest of these is from 270 to 290 ft below the lake bottom, on some of the profiles. Information from relatively short core samples taken in the middle third of the lake, in both the deeper basins and on the topographically high points, suggests that the deeper sub-bottom interfaces represent materials other than lake sediment. The lowest sub-bottom interface may be the surface of bedrock on some profiles, but this has not been confirmed. Glacial till deposits undoubtedly are represented by some of the interfaces. Deep drilling will be required to provide for identification of the materials.

## VERTICAL PROFILES OF BOTTOM SEDIMENTS

Core samples have been taken to investigate the vertical distribution of sediment types in the upper several feet of the bottom materials, to discover any changes which may have occurred during the late glacial to recent time, and especially to detect, if possible, any changes resulting from man's activity in the region.

All of the core samples taken in the years 1964 through 1966 have been extruded and described on full-scale diagrammatic logs, and approximately two-thirds of them also were photographed in color. The logs and photographs are filed in the Great Lakes Research Divison. A list of these cores, giving location, depth of water, and brief notes on their character, is given in Table 1.

### RESULTS

The cores taken and logged in this study have corroborated the results and conclusions reached in an earlier study (Hough 1955). These are summerized as follows: In the deeper northern parts of the lake basin there is a complete sequence of lake clay deposits, accumulated from glacial to the present time. The lower part of the clay, from immediately above the glacial till upward to a level that is estimated to represent about two-thirds of post-glacial time, is red in color and has no organic matter. Going farther upward, the color of the clay grades from red to gray with the color becoming generally darker gray all of the way to the surface of the bottom (with an exception to be noted later). The gray clay generally contains black color bands which contain iron sulfide and, in some cases, a small amount of organic matter.

This sequence of clays in deep water is interpreted as a record of a relatively barren lake from the last glacial event well toward the present time, in which no appreciable amount of organic matter was deposited in the bottom sediments; then of a change in conditions, occurring before civilized man reached the region, to a somewhat more productive lake in which a sufficient amount of organic matter was deposited in the deep-water sediments to cause a

TABLE 1. Core samples, Lakes Michigan, Superior, and Huron, taken in the years 1964-1966.

| Core Number | Latitude | Longitude | Depth (ft) | Core Length (m) | Photo | Remarks |
|---|---|---|---|---|---|---|
| | | | | Lake Michigan 1964 | | |
| 64-1 | 43°12'N | 86°55.5'W | 335 | 3.09 | x | Bluish-grey clay zone |
| 64-2 | 43°12' | 87°04' | 290 | 1.84 | x | Bluish-grey clay zone |
| 64-3 | 43°12' | 87°09' | 250 | | | |
| 64-4 | 43°13' | 87°10' | 300 | | | |
| 64-5 | 43°14' | 87°11' | 328 | 1.60 | | |
| 64-6 | 43°15' | 87°15' | 320 | 3.37 | x | Shells in tan clay zone, bluish-grey clay zone |
| 64-7 | 43°16' | 87°24' | 304 | 2.82 | x | Shells in sandy zone near top, bluish-grey clay zone |
| 64-62 | 42°52' | 87°16' | 362 | 3.25 | x | Shells in top 85 cm of core |
| 64-84 | 43°07.5' | 86°32' | 337 | | | |
| 64-85 | 43°08' | 86°36' | 350 | | | |
| 64-86 | 43°09 | 86°42' | 375 | | | |
| 64-87 | 43°17' | 87°07' | 310 | 3.51 | x | Bluish-grey clay zone |
| 64-88 | 43°17' | 87°18' | 318 | | | |
| 64-89 | 43°18' | 87°36.5' | 412 | | | |
| 64-90 | 43°18' | 87°39' | 390 | | | |
| 64-91 | 43°18' | 87°48' | 348 | | | |
| 64-92 | 43°18' | 87°48.5' | 280 | | | |
| 64-93 | 42°53' | 87°28' | 315 | 2.95 | x | Shell zone near top, bluish-grey clay zone |
| 64-94 | 42°57.5' | 87°26' | 327 | 2.89 | x | Bluish-grey zone |
| 64-95 | 42°52.5' | 87°28' | 327 | 1.57* | x | Shell zone, bluish-grey zone |
| 64-96 | 42°52' | 87°23' | 327 | 2.00* | | Till (?) zone |
| 64-97 | 42°52' | 87°20' | 339 | | | |
| 64-98 | 42°52' | 87°21.5' | 331 | 3.00 | | Bluish-grey clay zone |
| 64-99 | 42°51' | 87°20' | 343 | 2.51 | x | Bluish-grey clay zone |

TABLE 1. (Continued)

| Core Number | Latitude | Longitude | Depth (ft) | Core Length (m) | Photo | Remarks |
|---|---|---|---|---|---|---|
| | | | Lake Michigan 1964 (concluded) | | | |
| 64-100 | 42°53' | 87°20' | 344 | 1.94 | x | Shell zone, bluish-grey clay zone |
| 64-101 | 42°51' | 87°17.5' | 364 | 1.71 | x | |
| 64-102 | 42°50' | 87°15' | 384 | 1.67 | x | |
| | | | Lake Michigan 1965 | | | |
| 65-1-1 | 42°42.4' | 86°56.3' | 532 | 3.31* | x | Bluish-grey clay zone |
| 65-1-2 | 42°42.4' | 86°56.3' | 532 | 6.11* | | |
| 65-1-3 | 42°42.4' | 86°56.3' | 532 | 6.00* | | |
| 65-2-1 | 42°36.7' | 86°56.4' | 534 | 6.03* | | |
| 65-2-2 | 42°36.7' | 86°56.4' | 534 | 5.17* | | |
| 65-2-3 | 42°36.7' | 86°56.4' | 534 | 4.20* | | |
| 65-3-1 | 42°37.5' | 87°03.9' | 511 | | | |
| 65-3-2 | 42°37.5' | 87°03.9' | 511 | | | |
| 65-4 | 42°39.6' | 87°17.7' | 435 | 2.42* | | |
| 65-5 | 42°40.4' | 87°32.7' | 258 | 2.07 | x | Sandy at top |
| 65-6 | 42°39.6' | 87°29.7' | 300 | 2.83 | x | Sandy at top, bluish-grey clay zone |
| 65-7 | 42°38.8' | 87°27.8' | 347 | 3.14 | x | Sandy at top, bluish-grey clay zone |
| 65-8 | 42°38' | 87°25.3' | 360 | 1.76 | x | Bluish-grey clay zone |
| 65-9 | 42°37.3' | 87°22.8' | 386 | 1.65 | x | |
| 65-10 | 42°35.7' | 87°18.2' | 417 | 3.36 | x | Bluish-grey clay zone |
| 65-11 | 42°34.1' | 87°13.4' | 456 | 2.16 | x | |
| 65-12 | 42°32.3' | 87°07.7' | 478 | 3.29 | x | Bluish-grey clay zone |
| 65-13 | 42°30.8' | 87°12.6' | 458 | 1.87 | x | Bluish-grey clay zone |
| 65-14 | 42°29.3' | 87°17.3' | 411 | 2.96* | | Bluish-grey clay zone |
| 65-15 | 42°28' | 87°22' | 364 | 1.29 | x | |
| 65-16 | 42°27.2' | 87°24.4' | 347 | 1.97 | x | Wood 0.94 m from top |
| 65-17 | 42°26.6' | 87°26.6' | 328 | 3.15 | x | Sandy at top, bluish-grey clay zone |

TABLE 1. (Continued)

| Core Number | Latitude | Longitude | Depth (ft) | Core Length (m) | Photo | Remarks |
|---|---|---|---|---|---|---|
| | | | Lake Michigan 1965 (Continued) | | | |
| 65-18 | 42°25.9' | 87°28.8' | 303 | 2.89 | x | Bluish-grey clay zone |
| 65-19 | 42°21.7' | 87°24.6' | 310 | 3.15 | x | Bluish-grey clay zone |
| 65-20 | 42°21.7' | 87°22' | 330 | 3.16 | x | Bluish-grey clay zone |
| 65-21 | 42°21.7' | 87°19.4' | 345 | 3.09 | x | Shell zone |
| 65-22 | 42°21.7' | 87°16.9' | 376 | 3.44 | x | Shell zone |
| 65-23 | 42°21.7' | 87°14.3' | 388 | 1.72 | x | |
| 65-24 | 42°21.7' | 87°11.7' | 389 | 1.69 | x | Shell zone, bluish-grey clay zone |
| 65-25 | 43°10' | 86°43.3' | 366 | 3.45 | x | Bluish-grey clay zone |
| 65-26 | 43°14' | 87°17' | 314 | 2.37 | x | |
| 65-27 | 43°21' | 87°23.4' | 320 | 2.05 | x | Shell zone |
| 65-29 | 43°27.7' | 87°29.8' | 483 | 1.31 | x | |
| 65-30 | 43°30.4' | 87°32.7' | 453 | 1.42 | x | |
| 65-32 | 44°05' | 87°10.7' | 440 | 3.50 | x | Bluish-grey clay zone |
| 65-33 | 44°06.8' | 87°11.6' | 550 | 1.52 | x | |
| 65-34 | 44°24.1' | 87°22.5' | 304 | 0.50 | | Shell zone |
| 65-35 | 44°23.2' | 87°21' | 360 | 3.35 | x | Shell, sand, bluish-grey clay zone |
| 65-38 | 44°11' | 86°47.5' | 517 | 1.79 | x | |
| 65-40 | 43°52.1' | 86°38.3' | 225 | 3.41 | x | |
| 65-41 | 43°51.2' | 86°48.3' | 546 | 0.93 | x | |
| 65-42 | 43°36.3' | 86°53.4 | 332 | | | |
| 65-43 | 43°38' | 86°54' | 480 | 0.71 | x | Granules throughout core |
| 65-44 | 43°38' | 86°53.7' | 468 | 3.03 | x | Sandy at top, Bluish-grey clay zone |
| 65-45 | 43°38' | 86°53.3' | 465 | 2.73 | x | Sandy at top, Bluish-grey clay zone |
| 65-46 | 43°38' | 86°53' | 462 | 3.21 | | Bluish-grey clay zone |
| 65-47 | 43°38' | 86°52.7' | 467 | 2.54 | x | Sandy at top, bluish-grey clay zone |
| 65-53 | 44°16.7' | 86°43.1' | 750 | 1.89 | x | |
| 65-54 | 44°18.5' | 86°44' | 762 | 2.02 | x | |
| 65-55 | 44°21.7' | 86°45.5' | 738 | 2.92 | x | Bluish-grey clay zone |

TABLE 1. (Concluded)

| Core Number | Latitude | Longitude | Depth (ft) | Core Length (m) | Photo | Remarks |
|---|---|---|---|---|---|---|
| | | | Lake Michigan 1965 (Concluded) | | | |
| 65-56 | 44°23.5' | 86°46' | 780 | 2.06 | x | |
| 65-57 | 44°31.7' | 86°25.2' | 584 | 1.18 | | |
| 65-58 | 44°31.4' | 86°26.2' | 560 | 1.61 | | |
| 65-59 | 44°30.6' | 86°27.7' | 620 | 1.38 | x | |
| 65-60 | 44°29.6' | 86°29.6' | 700 | 1.50 | x | |
| 65-61 | 44°28.2' | 86°33' | 706 | 1.54* | x | |
| 65-62 | 44°26.5' | 86°36.4' | 753 | 1.81 | x | |
| 65-64 | 43°54.5' | 86°38' | 225 | 0.19 | x | Silty sand throughout |
| 65-65 | 43°53.5' | 86°39.9' | 295 | 0.86 | x | Many sand zones |
| 65-67 | 43°40.5' | 86°42' | 313 | 3.26 | x | |
| 65-68 | 42°48.6' | 86.59' | 510 | 3.17 | | |
| | | | Lake Superior 1966 | | | |
| SP-1 | 46°45.6' | 86°31.5' | 400 | 0.71 | | Sandy red clay |
| SP-2 | 46°46' | 86°31.4' | 270 | 0.78 | | Silty sand |
| SP-4 | 46°47.1' | 86°30.7' | 165 | 0.36 | | Sandy clay |
| SP-5 | 47°37.9' | 85°49.8' | 380 | 1.81 | x | Many sand zones |
| SP-6 | 47°32.5' | 85°42.5' | 640 | 1.57 | x | Bluish-grey clay zone |
| SP-8 | 46°53.5' | 84°58.5' | 205 | 1.91 | x | Sandy zone at top |
| SP-9 | 46°35.6' | 84°49.5' | 319 | 1.49 | x | Sandy zone at top |
| | | | Lake Huron 1966 | | | |
| HU-10 | 45°01' | 82°01' | 780 | 1.36 | x | |

*Core length after extrusion.

reduction of the iron generally and the formation of iron sulphide in the black color zones. This is considered a record of a small degree of natural eutrophication. Very few direct indications of the effects of man have been found, in the textural or mineralogical properties of the sediments, over most of the lake basin.

A few evidences of the presence of civilized man have been found. These are limited, in our present knowledge, to the materials in the surficial bottom sediments (cinders, nails, and tile fragments, and an odor of oil in a few samples from near the south end of the lake).

Further details from the study of the core logs include a record of an extreme low-water stage of the lake, which occurred between 10,000 and 4200 years before the present. The indication of this, described in detail by Hough (1955), is a zone of sandy and granular material and shells of a shallow-water pelecypod which occurs within the lake clay sequence at various depths down to 350 ft below present lake level and truncates earlier layers in the bottom deposits. The core samples collected and studied in the present project have verified this record. The maximum lowering of the lake surface, in the northern part of the basin, to a level 350 ft below the present, has been confirmed. The level of a separate lake in the southern part of the Lake Michigan basin, the existence of which was inferred in 1955, has been determined more accurately in the present study by a survey of the outlet area of that lake.

A detailed topographic survey of the sill area, made with a recording fathometer, showed the greatest depth on the sill to be 332 ft. Continuous seismic profiles of the area showed a sub-bottom interface 50 to 100 ft below the bottom, but the upper layer is considered to be pre-Lake Chippewa in age, because there has been very little sedimentation since Lake Chippewa time in that part of the lake. Core samples taken nearby, just to the southwest of the sill, show a maximum thickness of one foot of post Lake Chippewa sediment, and some cores show none. In general, glacial till is at or close to the bottom of the lake in the area. The present sill depth, 332 ft, is considered, therefore, to be sill depth of Southern Lake Chippewa.

The depth of the outlet stream is estimated as about 7 ft, plus or minus 5 ft; the elevation of the surface of Southern Lake Chippewa is therefore estimated as 325 ft, plus or minus 5 ft, below present lake level. This was 25 ft above the surface of the main body of Lake Chippewa, in the northern part of the basin.

## RADIOCARBON DATING OF HORIZONS

Organic remains, found in the bottom sediments at a few localities, have been dated by the radiocarbon method in order to obtain time-reference points for various events in the history of Lake Michigan.

As background for this work, a survey was made of all available radiocarbon dates bearing on Great Lakes history, and a card file was set up, which contains 75 dates. This is on file in the Great Lakes Research Division.

Radiocarbon dates obtained in the present study include the following:

Low-stage shells, sample M-1736, depth 315 ft; age 7580± 350 yrs B.P.
Low-stage shells, sample M-1571, depth 335 ft; age 7400 ± 500 yrs B.P.
Stump, in place, sample M-1888, depth 33 ft; age 6788 ± 250 yrs B.P.

In addition, a sample of shells from the maximum depth of the Lake Chippewa low stage, 350 ft, has been submitted for radiocarbon dating. This will give the age of the Lake Chippewa event, and it, in conjuction with the three dates listed above and others available in our files, will give the shape of the lake level-time curve for the period of rise of the lake surface from the low-stage to the next high-water stage, the Nipissing, which occurred at 4200 yrs before present.

## REFERENCES

HOUGH, J. L. 1955. Lake Chippewa, a low stage of Lake Michigan indicated by bottom sediments. Geol. Soc. of America Bull., V. 66, p. 957-968.

LANDES, K. K., G. M. EHLERS and G. M. STANLEY. 1945. Geology of the Mackinac Straits region. Michigan Geol. and Biol. Survey Pub. 44.

# THE SURFICIAL BOTTOM SEDIMENTS OF LAKE MICHIGAN

John C. Ayers

This paper briefly describes and summarizes the status of a program of mapping the surface sediments of the floor of Lake Michigan. While not a program of high priority in the total work of the Coherent-Area project, the survey and mapping was deemed worth-while on an as-opportunity-offers basis; information as to the nature of the surface sediments is requisite for certain aspects of the distributions of benthic organisms, and it also serves as a base-line study against which others later can assess whether sedimentary changes have taken place.

Eight hundred seventy-five samples that have been taken in fairly systematic fashion are shown in Figs. 1 through 4. For the most part the samples are in lines roughly perpendicular to shore, the lines being from 5 to 15 miles apart. Not all the potential lines have been taken and evident gaps show where they are still needed.

In each line the sampling intervals usually were: at 1-mile intervals from 1st through the 10th mile from the beach, at 2-mile intervals from the 10th through the 20th mile, and at 5-mile intervals thereafter. With the exception of 18 samples, all samples were taken with the dwarf orange-peel sampler. Navigation was by radar range and bearing out to about the 20th mile, beyond which navigation was by dead reckoning.

The sediment types presented here are classified by "field description." By "field description" is meant a combination of visual inspection, testing for odor, and feeling the sediment with the fingers on board the ship while the sample was fresh, and re-examination of the material in the laboratory under a binocular microscope with a metric scale in the field of view. The term is used as an opposite to any of the several means of designating sediment type from measured proportions of sand, silt, and clay determined in particle-size analyses.

Each sample has been placed subjectively in a sediment-type category on the basis of the field description of the uppermost sediment layer, even if it was only a thin surface layer. Layers underlying the surface layer are described in the field notes but have not been allowed to enter into the sediment categories depicted in the figures. For obvious reasons of bulk, the field descriptions are not presented in this paper. They are available from the Great Lakes Research Division. It is anticipated that they will be published when greater completeness of coverage has been attained.

The use of only the uppermost sediment layer is dictated by three primary considerations: 1) it is the uppermost sediment that bears upon benthic-animal distributions, 2) eutrophication-caused sediment changes will probably be first visible as significant color changes in the surface layer as it modifies toward the organic sediments, and 3) the development of unnatural odors will probably first occur in the uppermost layer and be most surely detected by shipboard examination of the fresh sample.

Despite its admitted subjective nature, we believe that the field description method of sediment classification has a real virtue in being immediately meaningful for comparisons in the field. Since this paper is merely a status report, it will not be discussed. We believe that the information presented in the figures is sufficient to justify its presentation.

Symbols used in the figures.

| | |
|---|---|
| ◐ | No Sample (Hard Bottom?) |
| ● | Till |
| ○ | Gravel (Granules to Boulders) |
| ◩ | Coarse to Very Coarse Sand |
| ■ | Medium Sand |
| □ | Very Fine to Fine Sand |
| ⬢ | Silty Sand |
| ⦰ | Clayey Sand |
| △ | Sandy Silt |
| ▲ | Sandy Clay |
| ▼ | Silty Clay |
| ▽ | Clayey Silt |
| ◆ | "Clay" |

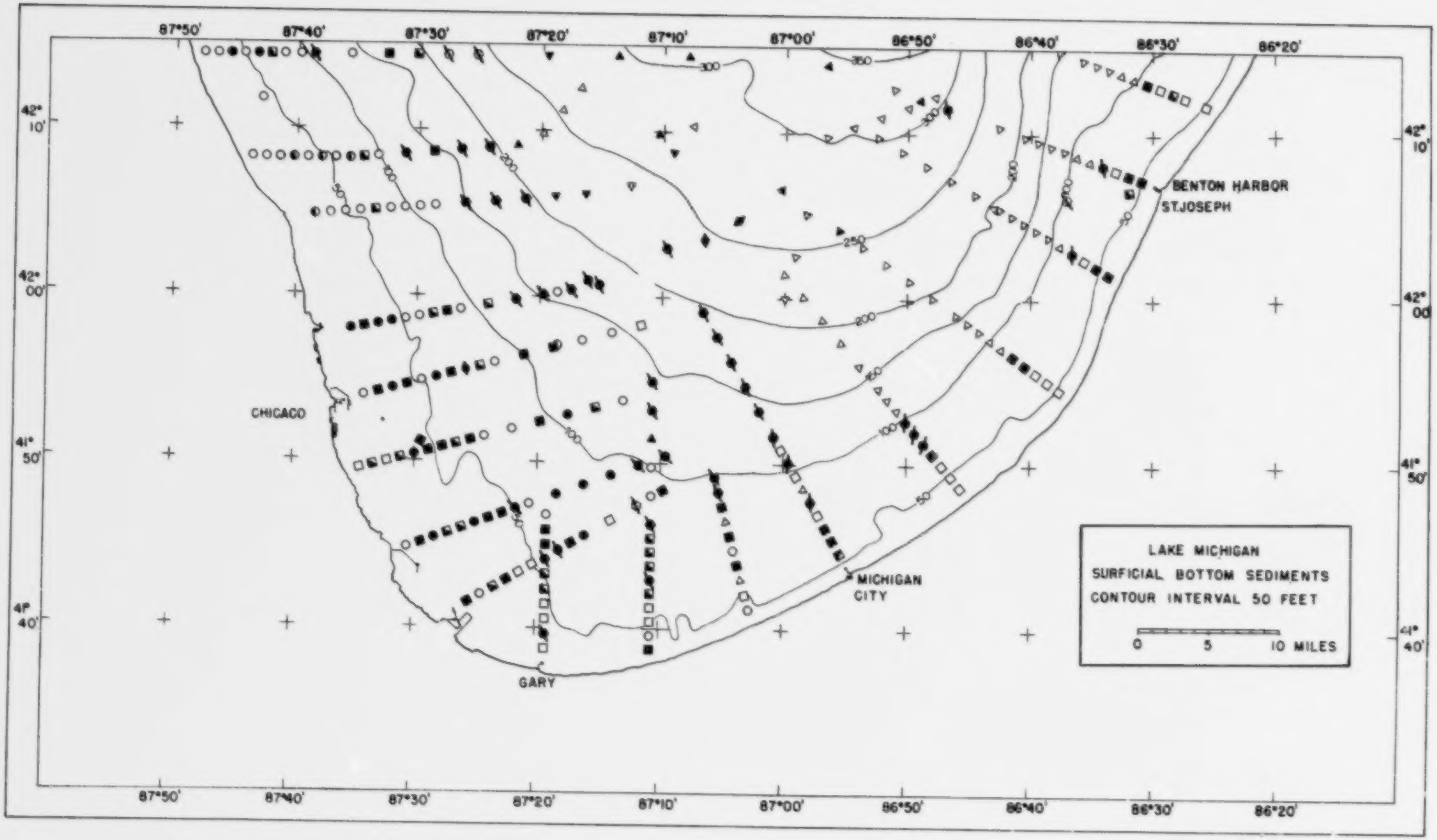

LAKE MICHIGAN
SURFICIAL BOTTOM SEDIMENTS
CONTOUR INTERVAL 50 FEET
0
5
10 MILES
CHICAGO
GARY
MICHIGAN CITY
BENTON HARBOR
ST.JOSEPH
87°50'
87°40'
87°30'
87°20'
87°10'
87°00'
86°50'
86°40'
86°30'
86°20'
42° 10'
42° 00'
41° 50'
41° 40'
50
100
150
200
250
300
350

FIG. 1. Lake Michigan surficial bottom sediments, south end of the lake to 42°15'N.

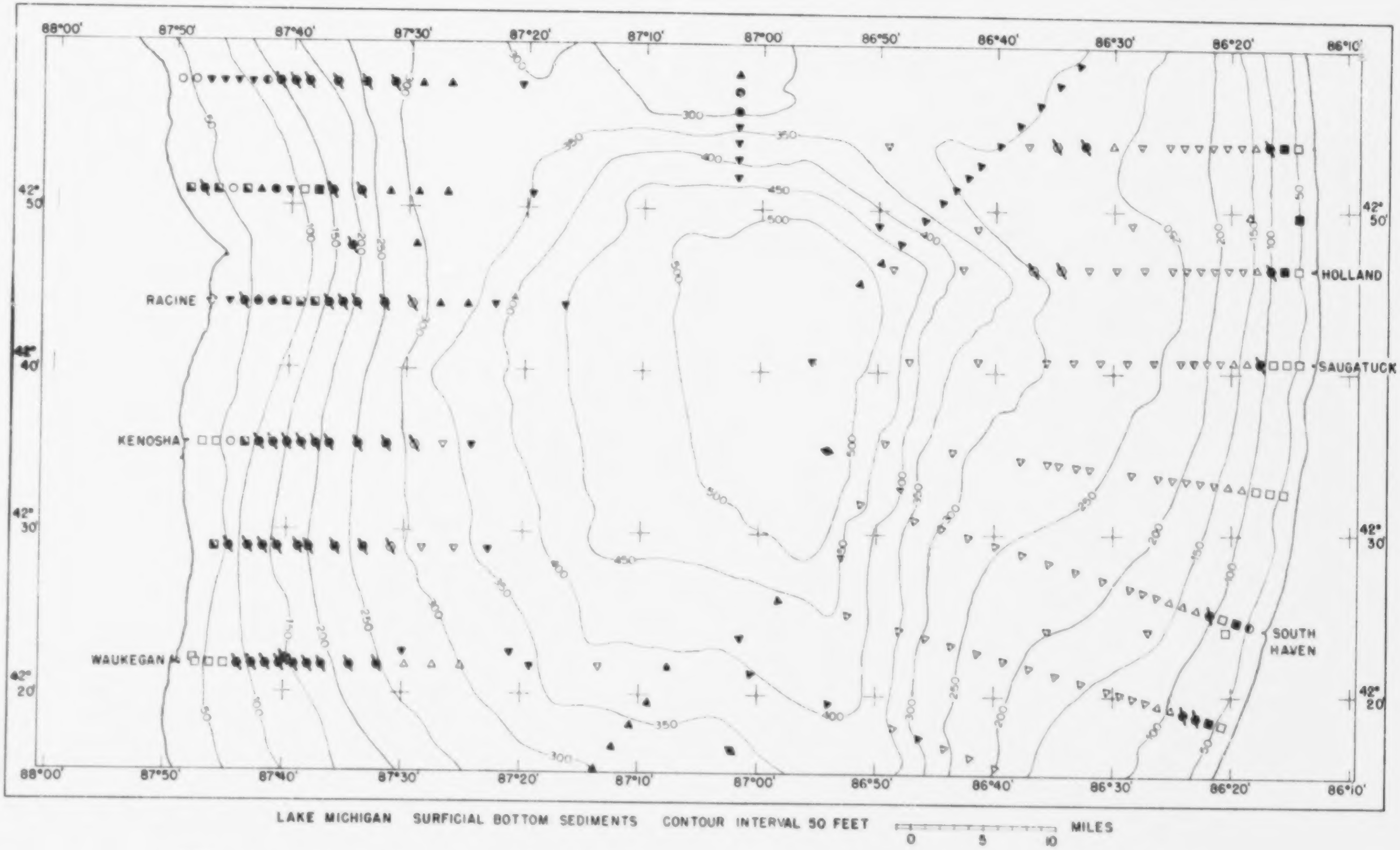

88°00'
87°50'
87°40'
87°30'
87°20'
87°10'
87°00'
86°50'
86°40'
86°30'
86°20'
86°10'
42° 50'
42° 40'
42° 30'
42° 20'
RACINE
KENOSHA
WAUKEGAN
HOLLAND
SAUGATUCK
SOUTH HAVEN
50
100
150
200
250
300
350
400
450
500
LAKE MICHIGAN SURFICIAL BOTTOM SEDIMENTS CONTOUR INTERVAL 50 FEET
0
5
10
MILES

FIG. 2. Lake Michigan surficial bottom sediments, latitude 42°15'N to 43°00'N.

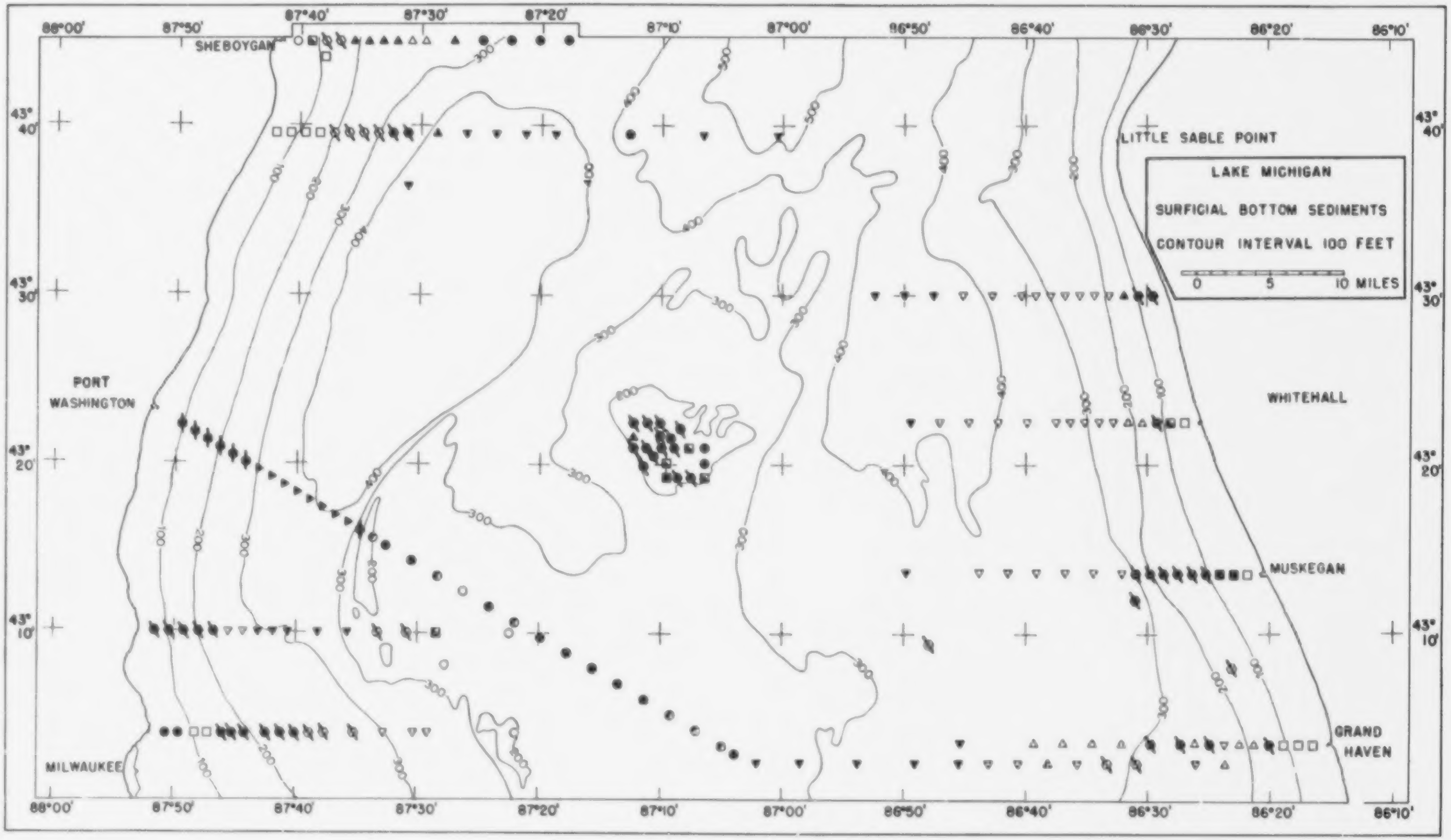

LAKE MICHIGAN
SURFICIAL BOTTOM SEDIMENTS
CONTOUR INTERVAL 100 FEET
0 5 10 MILES
SHEBOYGAN
LITTLE SABLE POINT
PORT WASHINGTON
WHITEHALL
MUSKEGAN
GRAND HAVEN
MILWAUKEE
88°00'
87°50'
87°40'
87°30'
87°20'
87°10'
87°00'
86°50'
86°40'
86°30'
86°20'
86°10'
43° 40'
43° 30'
43° 20'
43° 10'
100
200
300
400
500

FIG. 3. Lake Michigan surficial bottom sediments, latitude 43°00'N to 43°45'N.

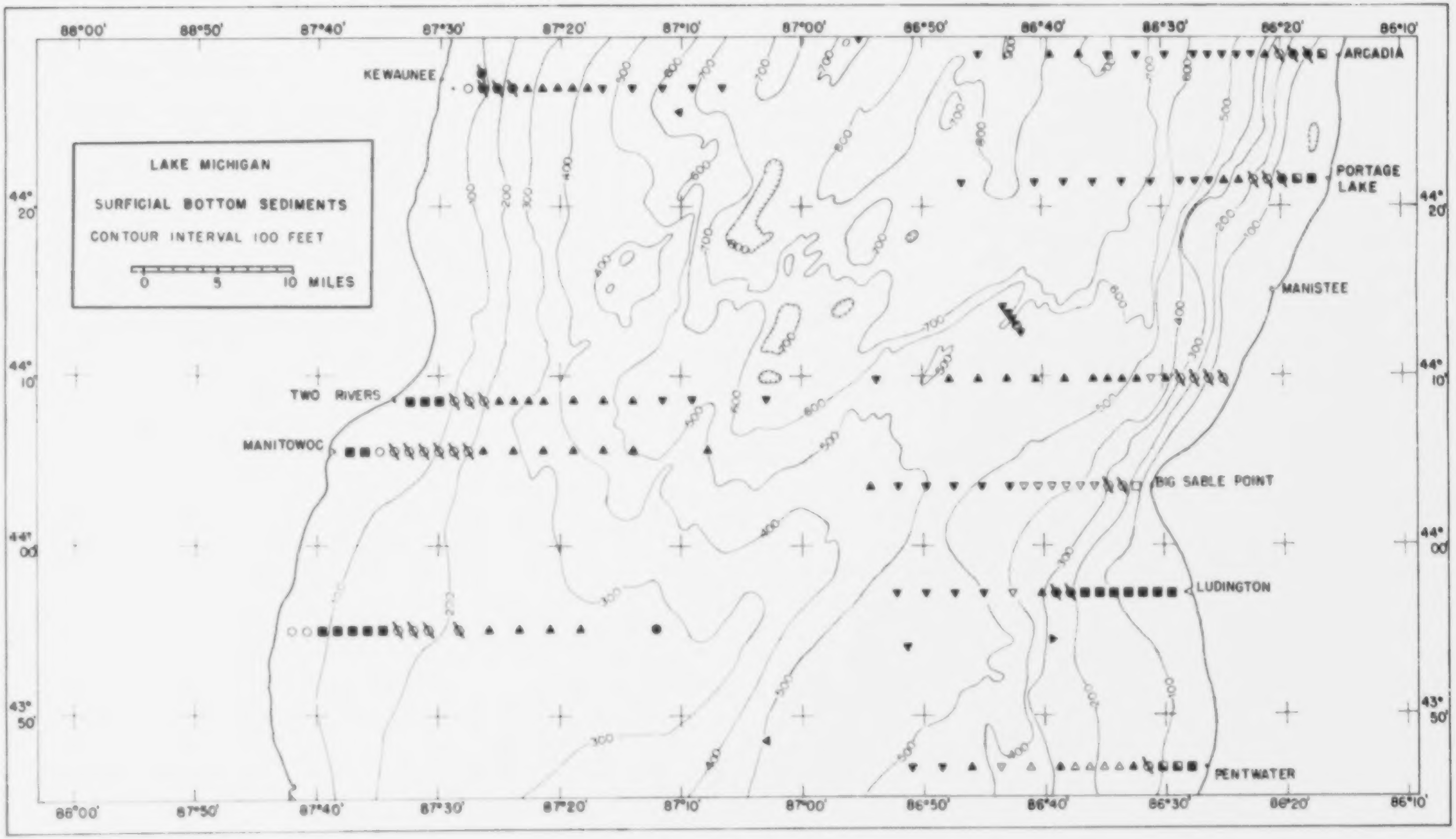

LAKE MICHIGAN
SURFICIAL BOTTOM SEDIMENTS
CONTOUR INTERVAL 100 FEET
0 5 10 MILES
KEWAUNEE
TWO RIVERS
MANITOWOC
ARCADIA
PORTAGE LAKE
MANISTEE
BIG SABLE POINT
LUDINGTON
PENTWATER
88°00'
88°50'
87°40'
87°30'
87°20'
87°10'
87°00'
86°50'
86°40'
86°30'
86°20'
86°10'
87°50'
44° 20'
44° 10'
44° 00'
43° 50'
100
200
300
400
500
600
700
800

FIG. 4. Lake Michigan surficial bottom sediments, latitude 43°45'N to 44°30 N.

# NEARSHORE SLOPE STUDIES IN LAKE MICHIGAN, 1964-1966

Lee H. Somers

Nearshore underwater studies prior to 1964 revealed abrupt changes in bottom slopes with sediments at the angle of repose in Sleeping Bear Bay (Lake Michigan). Excavation of the sediments at the base of the slope induced mass slumpage of slope sediments. In January 1964, metal reference stakes were placed at the crest and base of the slope to determine the nature of the geologic processes affecting the slope.

During the first 6-month period, approximately 8 inches of sediment was removed at the crest of the slope and 6 inches deposited at the base. Measurements made 19 months after the stakes were placed indicated that mass slumpage (?) had carried portions of the crest material including the crest reference stake to the base of the slope. Mass slumpage is indicated, since the crest reference stake remained in an upright positon during movement down slope. During the last 13 months of the study, only two inches of sediment deposition were noted at the base of the slope. Since large amounts of sediment were apparently slumping down slope, current activity was possibly removing sediments at the base of the slope.

An interesting phenomenon noted during the study was a progressive lakeward "building" of the crest. Based on a reference stake placed shoreward from the crest, sediment deposition built the crest approximately 5 feet lakeward during a 19-month period.

During the winter of 1965-66 these stakes were obscured by slumpage, etc. More reference stakes have been placed at this site, for resurvey at a later date. In addition, slopes at other sites were staked during the summer of 1966, for resurvey in 1967. These sites are: Sleeping Bear Bay (2 locations), Good Harbor Bay, Grand Traverse Bay (East). Additional observations in all of these areas will be required before accurate measurements and conclusions can be presented.

# THE REPRESENTATIVENESS OF RANDOM BOTTOM SAMPLES IN FOUR SELECTED LOCATIONS IN LAKE MICHIGAN

Lee H. Somers

## INTRODUCTION

The author, having observed and participated in several cases of detailed bottom sampling in inshore waters, became curious as to the real need for numerous and closely spaced samples in defining the characteristics of inshore sediments. This investigation was to determine the representativeness of a random sample of bottom sediment in typical inshore environments, by studying the variation of sediment properties at closely spaced intervals about an arbitrarily selected central point.

In each of four study areas, a central point was selected by dropping a marker from the surface to simulate the selection of a sampling station in the usual method of bottom sampling from a surface vessel. From the marker on the bottom, sampling lines were established by divers to provide successive samples around the marked central point. Bottom samples taken by the divers were analyzed for particle size distribution, and the usual phi-notation size distribution parameters were calculated.

The four study stations selected for this investigation were located on the northwest shore of the Lower Peninsula of Michigan about 21 miles north-northeast of Frankfort in the vicinity of Sleeping Bear Bay and Sleeping Bear Point. At Station I the bottom was of clean sand and was relatively level, with water depth of 28 to 29 ft. At Station II there was a gently sloping bottom of clean sand in depths from 5 to 15 ft. Station III had a level bottom of muddy sand at 65 ft of depth. The clean sand bottom of Station IV sloped from 6 to 58 ft.

## METHODS

Water depth and bottom topography were obtained by recording echo sounder. The position of the weighted marker dropped to the bottom was determined by horizontal sextant angles on charted navigation aids and charted landmarks ashore. The SCUBA diving team secured to the dropped station marker a weighted distance line marked in 10-ft intervals. Using this line, four 200-ft sampling lines were established from the station marker. These lines were 90° apart and formed two 400-ft transects, one parallel to shore and one normal to shore.

At Stations I, II and IV, one sediment sample was taken from under the station marker, and one each at 5 ft from the marker were taken on the four radial sampling lines; along each sampling line the third and subsequent samples were at 10-ft intervals. Station III at 65 ft was sampled at the marker, 10 ft from the marker, and after that at 20-ft intervals because of time limitations placed on the divers working at this depth. Samples were taken at exactly the measured distances to avoid any visual selectivity. An 8-ounce metal container was inserted approximately 2 inches into the sediment and moved laterally 3 to 6 inches to collect a 400-500 gram sample which was transferred to a plastic bag for transportation to the laboratory.

Sands containing little or no fine or coarse fractions were analyzed with the Emery settling tube (Emery 1938; Poole, Butcher and Fisher 1951) following the procedure of the Allan Hancock Foundation (Anonymous 1958). Material coarser than 2 mm was first sieved through a 2-mm screen and analyzed separately. The sieve method was used for one series of samples having a fine fraction too large for the settling tube technique and too small to warrant a separate fine-fraction analysis. Sand was sieved on a Rotap Sieve Shaker through the U. S. Standard Sieve Series; a 10-minute shaking period was used (Krumbein and Pettijohn 1938; Twenhofel and Tyler 1941). The results were converted to the phi notation by use of the conversion table of Page (1955). The areal variation in size parameters at each station is given in terms of a transect parallel to the shore and one normal to the shore.

## RESULTS AND DISCUSSION

Station I, in water depth of 28 to 29 ft, was located along the straight shore south of Sleeping Bear Point. It represented an inshore shallow-water level-bottom environment. Underwater observations revealed primarily a sand veneer with random exposures of an underlying gravel-cobble-boulder pavement. The pavement material was not analyzed and was plotted as rocky areas. If the rocky areas are ignored, the phi median and phi deviation values for the entire population of sand samples studied at this station did not indicate any significant variation in the line parallel to shore from those in the line normal to shore.

Station II was located along the straight shoreline farther south of Sleeping Bear Point. It represents a bottom sloping gently from 5 to 15 ft. No significant variation in size parameters was evident in the 400-ft transect parallel to shore. The transect normal to shore showed a decrease in grain size offshore, the median diameter decreasing with increase in depth and with distance from shore. The phi deviation measure increased slightly from shore lakeward, indicating that poorer sorting occurred with increasing depth and greater distance from shore.

Station III, in Sleeping Bear Bay, was on a level bottom at a depth of 65 ft. No significant variation in either phi median diameter nor phi deviation was indicated in the transects parallel or normal to the east shore of Sleeping Bear Bay.

Station IV was farther inshore in Sleeping Bear Bay. Here the bottom sloped gently from 6 to 24 ft but, at about 900 ft offshore, dropped abruptly from 24 to 56 ft in a horizontal distance of 60 ft. Along the transect parallel to shore no significant variation in size parameters was found. In the transect normal to shore, abrupt changes in phi median diameter and phi deviation occurred in the region of the abrupt break in slope. Here, in the range from 24 ft of depth to 56 ft, phi median diameter fluctuated from 1.56 to 1.12 to 1.78 to 1.37 and phi deviation fluctuated from 0.22 to 0.52 to 0.30 to 0.38.

## CONCLUSIONS

In the four open-lake areas studied, the following conclusions can be drawn, if the gravelly portions of area I are ignored:

Variation in grain-size distribution (in the sand sizes) was negligible whereever water depth was relatively constant. Small-scale variations in grain size occurred where water depth changed slowly. Greater variation in size parameters was evidenced in an area of abrupt slope change; here median diameter decreased and sorting became poorer with the rapid increase in depth.

It appears from the results of study of these four areas that depth profiles can be a guide in the choice of density of sampling, and that on nearly level bottom a random sample is usually representative of the material which is being transported and deported. It must be noted, however, that in area I, 25% of the stations had gravel; this material presumably is a lag concentrate. The conclusion, therefore, should be modified to state that a random sample does not always represent all the material in the vicinity of the sampling station. This is borne out by visual observation of other areas in northern Lake Michigan, where alternating patches of sand and of gravel occur.

## REFERENCES

ANONYMOUS. 1958. A field and laboratory manual of oceanographic procedures: Allen Hancock Foundation, University of Southern California, 167 p.

EMERY, K. O. 1938. Rapid method of mechanical analysis of sands: Jour. Sed. Petrology, vol. 8, no. 3, p. 105-111.

KRUMBEIN, W. C., and F. J. PETTIJOHN. 1938. Manual of sedimentary petrography: New York, D. Appleton-Century Co., 549 p.

PAGE, H. G. 1955. Phi-millimeter conversion table: Jour. Sed. Petrology, vol. 25, no. 4, p. 285-292.

POOLE, D. M., W. S. BUTCHER, and R. L. FISHER. 1951. The use and accuracy of the Emery settling tube for sand analysis. U. S. Beach Erosion Board, Technical Memorandum No. 23.

TWENHOFEL, W. H., and S. A. TYLER. 1941. Methods of study of sediments. New York, McGraw-Hill Book Co., Inc., 183 p.

# AN EVALUATION OF WIND SPEED MEASUREMENTS MADE FROM A RESEARCH VESSEL

H. K. Soo and Floyd C. Elder

## INTRODUCTION

Evaluation of the gross interaction between the air and water surfaces must rely, to a large extent, upon meteorological measurements made from ships. Fixed towers or spar-buoys are often employed for limited experimental measurements but do not produce information of a spatial coverage sufficient for large-scale evaluation of the energy fluxes. In some cases, such studies have used measurements made at stations surrounding the lake while making adjustments believed to compensate for lake-land differences. A number of studies have been conducted to define an empirical relationship between winds over water as related to simultaneously observed winds over the land, the study by Richards, Dragert, and McIntyre (1966) being the most recent and comprehensive.

These lake-land relationships are based necessarily on wind measurements reported by ships operating on the lakes, making the assumption that the reports are a correct measure of the prevailing wind. However, influences of anemometer exposure on wind speed measurements cannot be discounted when the exposure is on a platform as unstable as that afforded by a floating vessel. Indeed exposure on a fixed tower may, in some cases, produce significant systematic errors as shown by the model work of Hsi and Cermak (1965) and by Gill, Olson, and Suda (1966). Bogorodskii (1966) found that wind observations carried out aboard a research vessel may be up to 16% in error with an average error of 11.5%.

The Great Lakes Research Division has carried out an instrumentation program to provide continuous measurement of wind from its research vessels operated on the Great Lakes. The measurement and recording systems are described in the article by Elder, Soo, and Dute in this report. A large catalog of observational data has been accumulated towards the goal of defining the wind field, and ultimately, the energy fluxes over the lake.

In view of the extensive measurement program, it was believed important that an evaluation of the ship-induced error in wind measurements should be obtained. The measurement program on the U.S. Lake Survey, Lake Michigan Research Tower offered a unique opportunity for comparison of wind speed measured on an unobstructed fixed tower with that measured on a floating ship. The research vessels were scheduled to operate nearby the tower during several periods, and some comparative observations were obtained.

## DESCRIPTION OF RESEARCH VESSELS AND RESEARCH TOWER

Three research vessels operated by the Great Lakes Research Division have been instrumented to obtain wind measurements. The exposures of the anemometers differ due to individual ship design.

The INLAND SEAS is a 114-ft vessel on which the pilot house extends about 20 ft above water level. Anemometers are mounted on a forward mast 48 ft above water and on a bowsprit 15.5 ft above water and extending 21 ft forward of the ship's bow. It was hoped that the anemometer exposure at two levels would permit a measure of the vertical wind shear. It may be noted that the mast anemometer is mounted 28 ft above the highest solid obstruction and at the extreme top of the mast.

The MYSIS is a 50-ft vessel having a pilot house extending 14 ft above water level. The anemometer is mounted at the mast head 33 ft above water and 19 ft above all other obstructions. The HIGHLAND LASSIE is a 48-ft vessel with pilot house 14.7 ft above water. The anemometer mast extends 25 ft above water and 10.3 ft above the pilot house.

The ship mounted anemometers are of type F420-C, made by Electric Speed Indicator Co., and modified to provide a measure of the velocity relative to the bow and beam of the ship. The data are recorded as wind relative to the ship at 1-min intervals. Ship speed and heading are obtained from engine rpm and compass indication and are used to reduce the relative wind to true wind velocity. For use in this analysis, the wind measurements were reduced to total speed without regard to direction

The research tower (Fig. 1) was erected in 50 ft of water 1 mile from shore near Muskegon, Mich. The tower extended 50 ft above the water surface. A Bendix Aerovane wind system was mounted on the tower with the sensor at the 50-ft level. Sensitive three-cup, Clemet Model 011-1, anemometers were mounted at four levels to provide a measure of the vertical wind profile. The tower mounted anemometers had been recalibrated by the manufacturer prior to the measurement program and are accepted as being accurate in the tests here reported. The sensors were mounted on 5-ft arms extending upwind of the tower so that the tower influence is considered to be insignificant. The tower instrumentation is described in greater detail by Elder (1964).

## COMPARATIVE MEASUREMENTS

Individual ships were operated near the tower when schedules of ship and tower measurements would coincide. In some cases only the aerovane measurements were available from the tower while in others a measure of wind profile was determined.

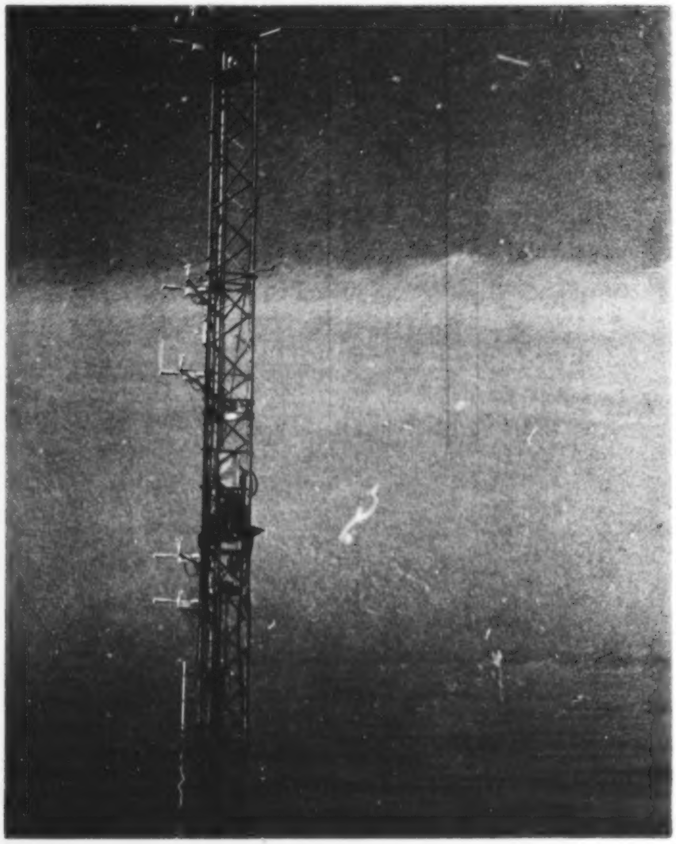


FIG. 1. Lake Michigan Research Tower.

On 22 July 1965 the R/V INLAND SEAS lay downwind from the tower with engines used only to maintain position and heading. The wind was light and steady from southeast and the sea was not sufficiently rough to cause significant roll of the ship. The ship lay for a period of 30 min bow to wind, 51 min stern to wind, and 45 min with starboard to wind.

The 1-min measurements of wind speed from both mast and bowsprit anemometers were averaged over the above periods. Tower measurements at 14.6, 12, 8 and 4 m were averaged over an hour nearest the period of measurement from the ship. The results are shown in Fig. 2.

The influence of the ship on the slope of the wind profile is very pronounced. When the ship is bow or broadside to the wind, it is apparent that the lower anemometer gives a relative measurement to large by about 30%. When the ship is stern to the wind, sheltering of the lower anemometer results in too small a relative wind speed. The mast anemometer gives a measurement larger than that measured on the tower in all cases. This is not believed due to ship influence but to absolute calibration errors discussed later.

On 23 September 1965 the INLAND SEAS again operated near the tower under sea conditions much too rough to permit lying on position. A course to the tower, then upwind for about 10 miles, downwind to the tower and quartering upwind from the tower was followed. Excessively heavy rolling was encountered throughout the period.

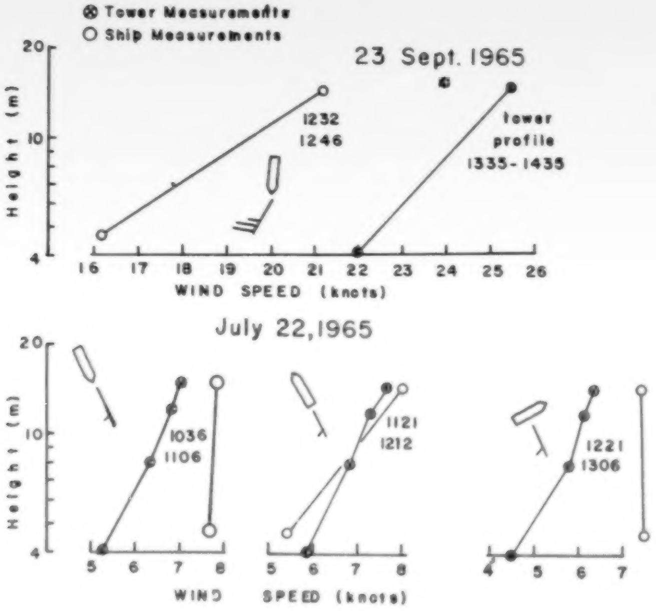


FIG. 2. Tower-ship comparisons of wind speed measurements.

Twelve-min periods of observation were selected for each portion of the course so that a measure of the wind profile could be obtained for each relative ship heading under the high wind conditions. The ship measured winds were averaged over the 12-min periods. The tower profile recording system was not operational during the actual ship measurements. The aerovane measurements from the tower are shown averaged over a 30-min period including the corresponding 12 min during which ship measurements were made. A tower-measured profile was obtained between 1335 and 1435 and is shown together with the other measurements in Fig. 3.

Ship influences similar to those observed in the first period are evident. From 0940 to 0952 when the ship had a broadside component to the wind, the lower anemometer recorded relatively too great a wind speed. Bow to the wind with the ship underway produces a wind profile somewhat too steep as compared to the tower profile measured at a later time after an increase in wind speed. Some "damming" effect of the ship at the lower level seems to be indicated. When heading downwind, the sheltering of the lower anemometer by the ship produces a profile much steeper than should be expected. At 1232 the ship again turned into the wind, recording a profile (Fig. 2) much steeper than had previously been measured under like heading. However, the lower anemometer was later torn away by waves and may have suffered damage during this period, although the observed effects are consistent with the earlier measurements heading into the wind.

Absolute calibration differences again appear to be present. In all cases except the 1216-1227 period, the ship mast anemometer gives a lower wind speed than was measured on the tower. In this case, the wind had increased during the

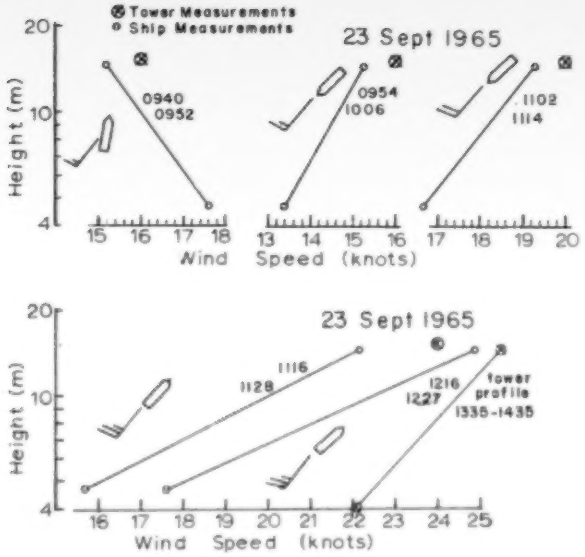


FIG. 3. Tower-ship comparisons of wind speed measurements.

later protion of the averaging period used for the aerovane data causing the average to be lower than the actual wind during the 1216-1227 minute period. This increase is shown by the profile measured on the tower at a later time. The absolute differences between the tower and ship measurements are summarized in Table 1.

The HIGHLAND LASSIE and MYSIS both were operated for periods anchored downwind from the tower. Anemometers were mounted at only the mast height on these vessels so that a comparative measure of the vertical wind profile was not obtained. The comparison of the absolute wind measurement with tower measurements, reduced to an equivalent height, are shown in Table 1. As was the case with measurements from the INLAND SEAS, a rather large and variable difference exists between the two measurements.

## DISCUSSION OF RESULTS

The limited periods of coincident measurements do not afford opportunity for statistical evaluation. The data were accumulated over the period of several months from different ships using different anemometers. A direct comparison of errors observed during the different periods is not, therefore, valid.

The influence of the ship is rather well defined for the case of the bowsprit anemometer on the INLAND SEAS. With the ship stern to the wind, the

TABLE 1. Summary of ship and tower mounted anemometer measurements (wind observations in knots).

| | Ship | Tower | Difference (tower-ship) | Percent Difference | Length of period (min) |
|---|---|---|---|---|---|
| INLAND SEAS | | | | | |
| Bow to Wind (mast anemometer) | | | | | |
| | 7.9* | 7.1 | -0.8 | -11.2 | 30 |
| | 15.3 | 16.0 | 0.7 | 4.4 | 12 |
| | 19.3 | 20.0 | 0.7 | 3.6 | 12 |
| Bow to Wind (bowsprit anemometer) | | | | | |
| | 7.7* | 5.5 | -2.2 | -39.6 | 30 |
| Stern to Wind (mast anemometer) | | | | | |
| | 8.0* | 7.6 | -0.4 | - 5.2 | 51 |
| | 22.2 | 24.0 | 1.8 | 7.5 | 12 |
| | 24.9 | 24.0 | -0.9 | - 3.7 | 11 |
| Stern to Wind (bowsprit anemometer) | | | | | |
| | 5.4* | 6.1 | 0.7 | 11.7 | 51 |
| Broadside or Quarter to Wind (mast anemometer) | | | | | |
| | 7.4* | 6.4 | -1.0 | -15.6 | 45 |
| | 15.2 | 16.0 | 0.8 | 5.0 | 12 |
| | 21.2 | 24.0 | 2.8 | 11.6 | 12 |
| Broadside or Quarter to Wind (bowsprit anemometer) | | | | | |
| | 7.5* | 4.8 | -2.7 | -56 | 45 |
| HIGHLAND LASSIE | | | | | |
| Bow to Wind (mast anemometer) | | | | | |
| | 8.9 | 10.3 | 1.5 | 16.9 | 24 |
| | 9.3* | 10.7 | 1.4 | 15.1 | 60 |
| | 7.9* | 9.3 | 1.5 | 19.0 | 30 |
| | 12.0* | 10.0 | -2.0 | -16.6 | 30 |
| | 12.3* | 16.7 | 4.4 | 36.7 | 54 |
| Stern to Wind (mast anemometer) | | | | | |
| | 11.0 | 11.5 | 0.5 | 4.5 | 30 |
| | 13.3 | 17.3 | 4.0 | 30.8 | 30 |
| MYSIS | | | | | |
| Bow to Wind (mast anemometer) | | | | | |
| | 7.7* | 7.8 | 0.1 | 1.3 | 30 |
| | 7.9* | 8.8 | 0.9 | 11.4 | 30 |
| | 8.2* | 8.8 | 0.4 | 4.9 | 30 |
| | 7.8 | 8.8 | 1.0 | 12.8 | 30 |

*Ship not underway.

sheltering effect is obvious and low readings are always obtained. Broadside or quarter to the wind produces a convergence of flow around the ship with an increase in the measured wind speed at the bowsprit. When lying stationary bow to the wind on 22 July, the recorded wind speed was too great while heading into the wind under heavy seas on 23 September gave measurements believed only slightly too small. It may be concluded from these results that wind measurements made from anemometer exposure on a bowsprit can be reliable only when the ship is underway into the wind, and even then high order of accuracy cannot be expected.

Measurements made on the masts do not evidence a systematic error that can be attributed to the ship influence. If such an influence exists, it is hidden in errors due to other factors. The absolute calibration of the anemometers, effect of the roll of the ship and error in ship speed are factors that could contribute to the observed error.

## ANEMOMETER CALIBRATION

In practice, the Electric Speed Indicator wind speed transmitters are individually calibrated on the ship as an integral unit with the recording system. The manufacturer specifications of the sensors state that 300 rpm is equal to 28.1 knots, ± 1 knot. A Borg, Model 1003-45Y, 300 rpm, synchronous motor is used to drive the speed transmitter while the recorder gain is adjusted such that a value of 28.1 knots is indicated. This procedure allows for accurate calibration except for the actual rotation rate of the anemometer cups.

The calibration method employed leaves uncertain the accuracy of the cup calibration. Two units were checked for calibration in the wind tunnel of the Department of Meteorology and Oceanography, The University of Michigan, to determine compliance to the stated calibration. The speed transmitters were calibrated with the 300 rpm motor as in use on the ships. The cups and transmitters were than installed in the wind tunnel and a calibration with reference to the pitot tube measured tunnel velocity was obtained. The two units calibrated produced the calibrations shown in Fig. 4. The tunnel speeds required to produce 300 rpm were 26.9 and 29.3 knots. The published starting speed is 2 knots while both units gave an indicated starting speed of about 1.5 knots. The measured calibration falls only slightly outside the stated accuracy of ± 1 knot but amounts to an 8.6% difference between the two anemometers.

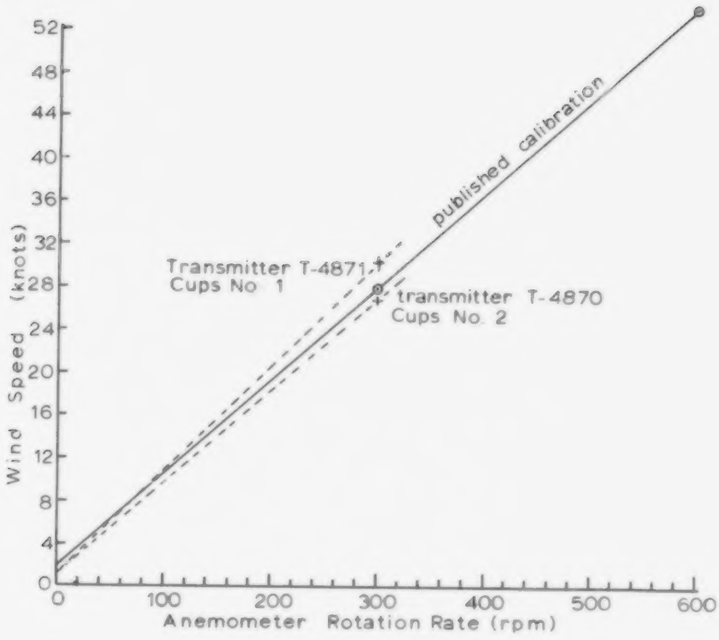


FIG. 4. Wind tunnel calibration of two electric speed indicator anemometers.

## EFFECT OF SHIP ROLL ON WIND SPEED MEASUREMENTS

The wind speed recorded on a ship is the air movement relative to the point at which the anemometer is mounted. A lateral component due to rolling of the ship is added and results in a greater than true relative wind at the point of measurement. Deacon, Shippard, and Webb (1956) have analyzed the influence of ship rolling and have shown for a harmonic rolling motion with bow to the wind that

$$U_T^2 = U_A^2 + (2\pi h\alpha/T)^2 \sin^2 \omega t$$

where

$U_T$ = Total relative wind
$U_A$ = Actual relative wind
$h$ = Height anemometer above roll axis
$\alpha$ = Rolling amplitude in radians
$T$ = Roll period
$\omega$ = $2\pi/T$
$t$ = Time

Thus, the resultant relative wind is the sum of the true relative wind to which is added a harmonic contribution that is always positive. If the recording system averages over time or if a number of observations are averaged, a net positive error will result.

Deacon has shown that, if an average over several roll periods is taken and higher order terms are neglected in the integration, the above relation reduces to

$$\frac{U_T}{U_A} = 1 + 1/4 \left[\frac{2\pi h\alpha}{TU_A}\right]^2$$

For the INLAND SEAS operating in 4-ft seas, typical values of the variables as per the captain's experience are

$\alpha$ = 0.3 radians
$T$ = 5 seconds
$h$ = 14.6 m (for the mast anemometer)
$U_A$ = 10 mps

Substituting we have

$$\frac{U_T}{U_A} = 1.075$$

giving an error of 7.5% in the measured true relative wind if the anemometer responds fully to the velocity due to ship roll.

Cup anemometers, however, have significant inertia and do not respond instantly to changes in wind speed. The rate of response can be described in terms of a "distance constant" being the length of a fluid column that must pass the sensor before 63% of an actual change in velocity is indicated. The distance constant for the Electric Speed Indicator anemometer has been determined as 26 ft (see Schubauer and Adams 1954).

When a sensor is exposed to a harmonic fluctuation such as the roll velocity of a ship, it can be shown that the degree to which the sensor responds is determined by the wavelength of the fluctuations and the distance constant of the sensor. The ratio of indicated to actual magnitude of the fluctuating variable can be determined. A summary of the response of several anemometers as a function of fluctuation wavelength has been compiled by Gill (1965) and is shown in Fig. 5.

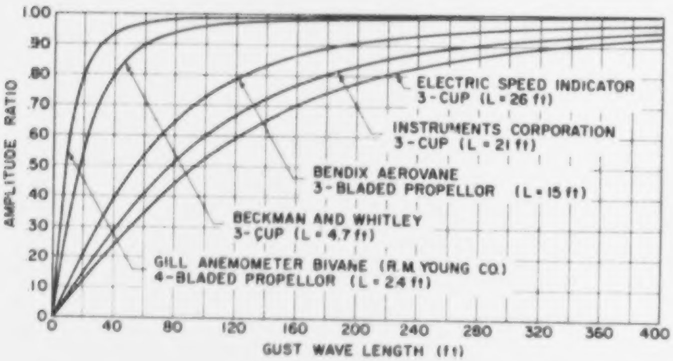


FIG 5. Response of several typical wind speed sensors to sinusoidal wind speed fluctuations of varying gust wave length (from Gill 1965).

For the INLAND SEAS operating in conditions as described above, the wavelength of the roll velocity is about 14 ft. Therefore, the Electric Speed Indicator anemometer, having a distance constant of 26 ft, will respond to less than 10% of the actual roll velocity. It may be noted that a fast response anemometer such as the Beckman and Whitley 3-cup anemometer would have given nearly 50% response with a correspondingly greater error due to ship roll. It is concluded that the roll of the ship produces no more than a 1% error in the measured relative wind speed.

## VARIATION IN SHIP SPEED

The true wind speed is obtained as the sum of the relative wind and the ship speed vectors. Any error in the measurement of ship speed, therefore, produces an equal error in the true wind. Indication of the ship speed, in the absence of precise navigation equipment, is obtained from propeller rotation rate. The ship speed relation to propeller rotation is obtained averaging travel time over known distances for several voyages. The relationship should give acceptable accuracy for the ship traveling in light wind with smooth seas and no drift current.

A quantitative measure of the variation in ship speed under different conditions has not been obtained. It is qualitatively known that the ship will be slowed by a head wind or sea and aided by a trailing sea or wind. The ship speed, as determined from propeller rpm, is overestimated when operating in a headwind and underestimated with a following wind in the absence of significant drift current. Since the true wind is the vector sum of the relative wind and the ship speed, the net effect of the errors in ship speed for the above causes is to underestimate the true wind by the amount of ship speed error. From general experience and as a result of a few actual measurements, it is estimated that error due to this cause may be about one knot when operating in moderate seas.

The influence of ship speed error can be seen in the results shown in Figs. 2 and 3. On 22 July the ship mast anemometer overestimated the wind speed, apparently due to a calibration error, when the ship was stationary. However, using the same calibration, on 23 September the wind speed was underestimated when underway in a heavy sea.

## CONCLUSIONS

Quantitative conclusions are not possible from this study due to the small amount of data available. However, several qualitative results seem to be apparent.

1. The roll of the ship does not produce significant error when a slow response anemometer is used as a sensor.

2. The influence of the ship is not detectable when the anemometers are mounted on a well exposed mast.

3. Bow mounted anemometers cannot be used to measure accurately the wind profile but may give useful information when the ship is underway into the wind.

4. The largest contribution to errors in wind measurement from research ships is the actual calibration uncertainty and the uncertainty in the measurement of ship speed.

5. A reasonable estimate of the error in wind speed measurement from a well exposed anemometer on a ship, based upon the experience reported herein, would be about 5%. However, as shown in Table 1, individual cases may be expected where the errors may exceed this value.

## REFERENCES

BOGORODSKII, M. M. 1966. Comparison of gradient observations of wind velocity carried out with a Froude spar-buoy and a shipboard gradient instrument. Okeanologiia, 6(2): 347-354.

DEACON, E. L., P. A. SHIPPARD, and E. K. WEBB. 1956. Wind profiles over the sea and the drag at the sea surface. Australian J. Phys., 9(4): 511-541.

ELDER, FLOYD C. 1964. A facility for air-sea interaction study on Lake Michigan. Proc. 7th Conf. on Great Lakes Res.; Univ. Michigan, Great Lakes Res. Div. Pub. No. 11: 228-237.

GILL, GERALD C. 1965. On the dynamic response of meteorological sensors and recorders. Paper presented at the First Canadian Conference on Micrometeorology, Toronto, Canada.

__________, LARS E. OLSON, AND MOTOZO SUDA. 1966. Errors in measurement of wind speed and direction made with tower- or stack-mounted instruments. Univ. Michigan, College of Engineering Report 06973-1-P.

HSI, G., and J. E. CERMAK. 1965. Meteorological-tower induced windfield perturbations. Colorado State Univ., Report CER 65 GH-JEC-49, AD 623946, 23 p.

RICHARDS, T. L., H. DRAGERT, and D. R. McINTYRE. 1966. Influence of atmospheric stability and over-water fetch on winds over the lower Great Lakes. Mo. Weather Review, 9(7): 448-453.

SCHUBAUER, G. B., and G. H. ADAMS. 1954. Log of Anemometers. Bur of Standards Report No. 3245.

# THE INFLUENCE OF STABILITY ON CLOUD COVER AND INCIDENT SOLAR RADIATION OVER LAKE MICHIGAN

Kenneth L. Davidson

## INTRODUCTION

There is a need for methods which can be used to relate weather conditions existing over a large lake to conditions which are observed at shore stations, or from ships, and which are recorded and readily available in tabulated form. Biologists need weather information when they are investigating changes in the type and number of organisms living in the water and which are influenced by the conditions existing over the lake. Cloud cover, for example, affects the penetration, into the water, of light which is important in biological changes in the lake. Shore-station observations over a span of many years are available in the form of local climatological summaries and are basic sources of lake weather information, particularly when information on past conditions is needed.

The present study is designed primarily to gain information concerning cloud conditions over Lake Michigan and the resulting effect of the cloud cover on incident solar radiation. The difference in cloud cover on opposite sides of the lake should be directly related to the influence of the lake in increasing or decreasing cloud development. Since it appears that cloud development due to the lake's effect has discrete patterns, data are categorized according to stability and flow factors. Interpolation to cloud and radiation conditions over the lake must take into account the dynamics of the air-lake interaction in the observed differences across the lake. Procedures used in analyzing data with respect to cloud cover are applied also to study the changes occurring in the surface air and dew point temperatures.

## APPROACH

Differences in cloudiness between two stations which are separated by Lake Michigan (Milwaukee, Wis., and Muskegon, Mich.) are shown in Fig. 1 (USWB 1959). Since the prevailing direction of the wind over the lake is westerly, the figure provides an insight into the conditions existing over Lake Michigan. This figure shows that the eastern shore (Muskegon) has more cloudiness during the winter months when unstable conditions prevail over the lake and less cloudiness during the summer months when stable conditions prevail. This seasonal variation in cloud differences across the lake indicates that stability is important in overlake cloud conditions.

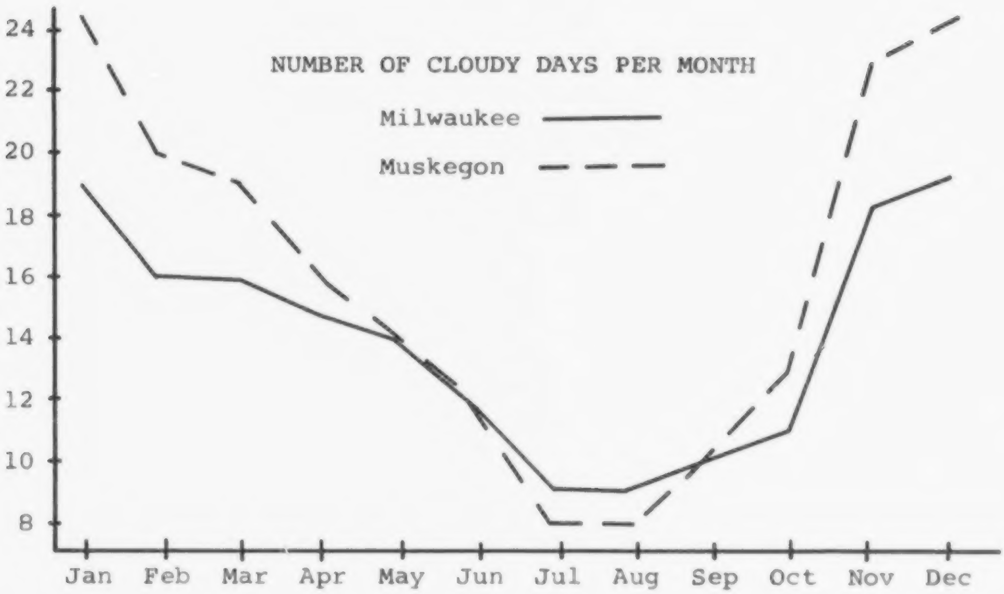


FIG. 1. Number of cloudy days per month at Milwaukee, Wis., and Muskegon, Mich., averaged over 15 years. After Tech. Paper No. 35, USWB 1959.

Since air masses move toward the Great Lakes under the influence of the general westerly circulation, a large percentage of flows over Lake Michigan are from the southwest, west, and northwest. By using appropriate stations, it is possible to make comparisons of weather parameters with respect to the flow across the lake. Figure 2 shows the shore stations used in this study, with Chicago (Midway), Milwaukee, and Green Bay as upwind stations and Muskegon as the downwind station. The figure also shows that flow from southwest or northwest has greater overwater fetch than flow from the west.

Lake Michigan is located in the interior of a continent with varying surface features. Air masses moving through this region could experience systematic changes in cloud cover, temperature, and dew points because of influences other than the lake. A possible example of this can be seen by comparing cloud observations at two stations which are on the same side of the lake. Figure 3 shows the difference in cloudy days per month between Madison, Wis., and Chicago (Midway). Because there appear to be systematic differences in cloudiness between two overland stations, this study uses a control method to take possible non-lake influences into account. This is done by making a statistical comparison of cloud cover changes between two stations with no overwater trajectory and the cloud cover changes between stations on opposite sides of the lake. The stations for the overland comparison are selected so that the distances and trajectory directions between the pairs of overland stations are approximately the same as those for the corresponding pairs of overwater stations. Using Madison as the upwind station for the overland comparison satisfies these requirements for all three wind categories (Fig. 4).

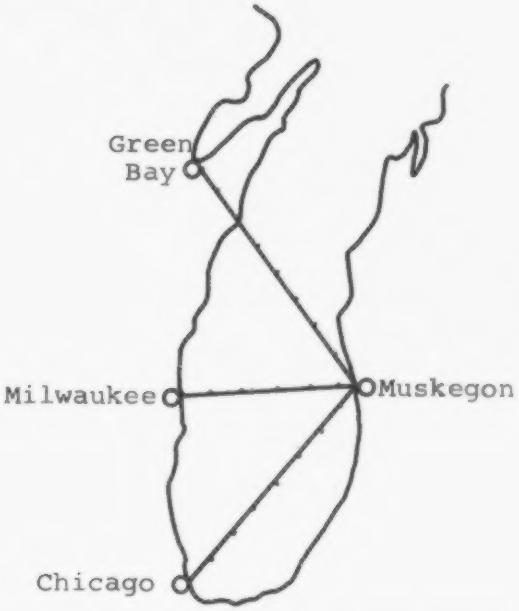

Green Bay
Milwaukee
Muskegon
Chicago

FIG. 2. Lake Michigan vicinity stations used for overwater comparisons.

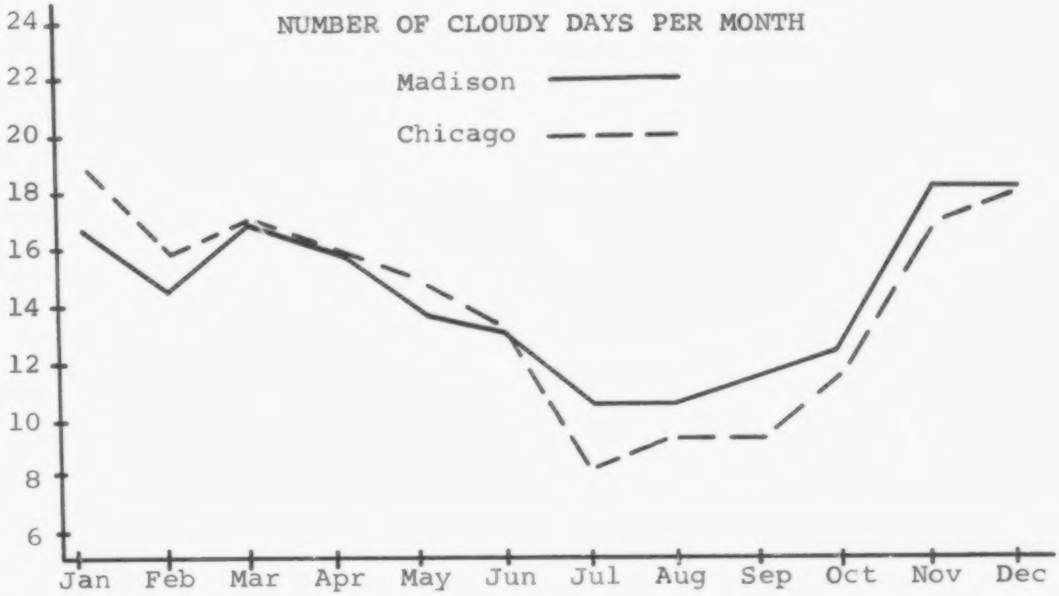
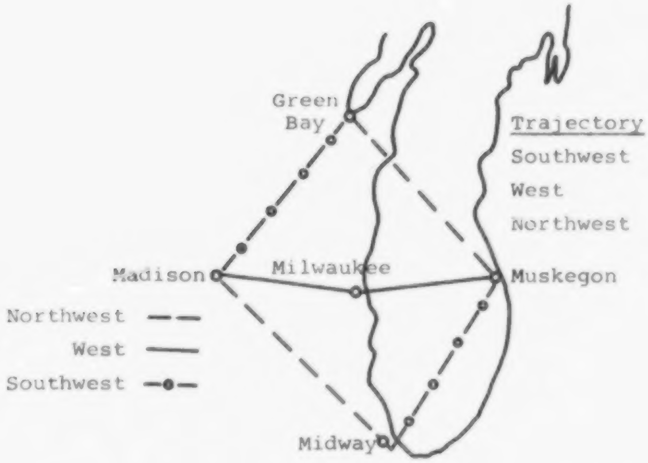


FIG. 3. Number of cloudy days per month at Madison, Wis., and Chicago (Midway), Ill., averaged over more than 15 years. After Tech. Paper No. 35, USWB 1959 and 1964.



| Trajectory | Angles Included |
|---|---|
| Southwest | 200° - 248° |
| West | 248° - 290° |
| Northwest | 290° - 350° |

FIG. 4. Network of stations used for overwater and overland comparisons with wind direction intervals for different flow directions.

The flows across the lake are grouped into general categories as being from the southwest, west, or northwest as determined by the direction of the 850 mb wind with a wind direction interval of approximately 45° in each category (Fig. 4). The 850 mb wind, which is obtained from Northern Hemisphere Data Tabulations, is that observed at Green Bay, Wis. (the area's most representative station for the study). The limiting wind directions for flows from southwest and northwest are selected for particular reasons. For the southwest case it is important that air arriving at Muskegon have a history over the lake. A more southerly direction than 200° would not have sufficient overwater fetch. For the northwest case it is desired that the air mass under consideration have no history over Lake Superior. Though the 350° direction includes part of Lake Superior, it is only the narrower western portion.

Stability is determined by using the air-water temperature difference, the air temperature being the dry bulb temperature at the upwind station while the water temperature is the water surface temperature obtained from a vessel at approximately a mid-lake position. The mid-lake surface water temperatures are obtained from microfilms of the ship's log of the CITY OF MIDLAND. Air-water temperature differences are grouped in intervals of 10°F from +50°F to -50°F.

Sky conditions, temperatures and dew point temperatures are obtained from the Monthly Local Climatological Data (Supplement) summaries of the U.S. Weather Bureau (1964). In selecting cloud data, only the clouds with bases from the surface to 10,000 ft (3 km) are considered. This height interval was chosen on the basis of the findings of George (1940) and Lenschow (1965) which indicate that the turbulent inversion is raised from its initial level of about 1 km up to 2 to 2-1/2 km when relatively cold air crosses over a lake the size of Lake Michigan.

The statistical test selected to compare the significance of the overlake and overland difference, the "difference of means," Panofsky and Brier (1958), is defined as the ratio:

$$T = \frac{\overline{\Delta LK} - \overline{\Delta LD}}{\left[\dfrac{VR\Delta LK + VR\Delta LD}{N - 1}\right]^{1/2}}$$

where

$\Delta LK$ = mean difference across the lake
$\Delta LD$ = mean difference across the land
$VR\Delta LK$ = variance of the difference across the lake
$VR\Delta LD$ = variance of the difference across the land
$N$ = number of observations

The test is designed to determine the significance of the population differences between two sets of data (see Appendix 1). The significance of the lake effect increases with increasing absolute value of the ratio while the sign of the ratio indicates the direction of the effect, i.e., to increase or decrease cloudiness.

Since we wish to detect changes in a single air mass as affected by the lake, those conditions where a front exists between the stations and where flows are not within the categories described (the 850 mb wind direction more easterly than 350° or 200°) are excluded from the study. This selection of significant synoptic situations provides 3588 hr of usable data which amounts to 41% of the hours during the year, December 1962 through November 1963, Table A, Appendix 2.

## RESULTS

Cloud, temperature, and dew point results of the first part of the study are given in Figs. 5-10 and summarized in Table B (Appendix 2). The curves in Figs. 5-10 represent least square quadratic equations ($Y = a_0 + a_1X + a_2X^2$), where $X = (T_{air} - T_{water})$. The results were investigated by "least square" criterion for linear, exponential, and quadratic relationships. In all cases except the "difference-of-means" for flow from the west, the quadratic relation has the lowest absolute percentage error and is used to delineate the results between the different flows.

Figure 5 gives the "difference-of-means" results from the overwater and overland cloud cover comparisons. For flow from the southwest, there appears to be little statistical evidence of the lake's effect during unstable conditions, indicating that the cloud change over water was not significantly different from the cloud change over land. For flow from both the west and northwest, there appears to be a significant lake effect for unstable conditions. Surprisingly, for flow from the west (which has the shortest overwater trajectory) there appears to be the greatest lake effect.

Figure 6 shows cloud differences obtained in the overwater comparisons. For all three flows, there appear to be significant increases in cloud cover when the air temperature is more than 20°F colder than the water temperature. This difference decreases as the stable condition is approached, and there is little cloud cover difference throughout the stable conditions.

Although the 850 mb flow was used to categorize flows, temperature and dew point differences at the surface were investigated using the same procedures described for the cloud conditions.

Air temperature results (Figs. 7,8) indicate that the flux from the air to the water or water to air is dependent on stability. There appears to be considerable warming of the air under unstable conditions (water warmer than air). On the other hand, the flux of heat from the air to the water appears to be small under stable conditions (water is cooler than the air).

The dew point temperature results (Figs. 9,10) show that the flux of moisture is significant under unstable conditions and decreases as the stable condition is approached. Moisture transport from the air during stable conditions is perhaps negligible.

A problem in this study shows up clearly in the air temperature results, that is, what to use in defining flow across the lake when comparing surface observations. Particularly, flows from the southwest under lower categories of instability (water less than 20°F warmer than the air) show cooling of the air as it crosses a relatively warm lake (Fig. 8). This phenomenon is most unlikely and the discrepancy is probably caused by the fact that on many occasions the surface wind may be significantly out of phase with the 850 mb wind, which was used to define the flow in this study. A different way of defining the flow may have to be used to get a proper analysis of these surface parameters (temperature and dew point temperature).

## SOLAR RADIATION

The above results are used to investigate solar radiation on Lake Michigan during situations when the lake effect is important in cloud cover changes.

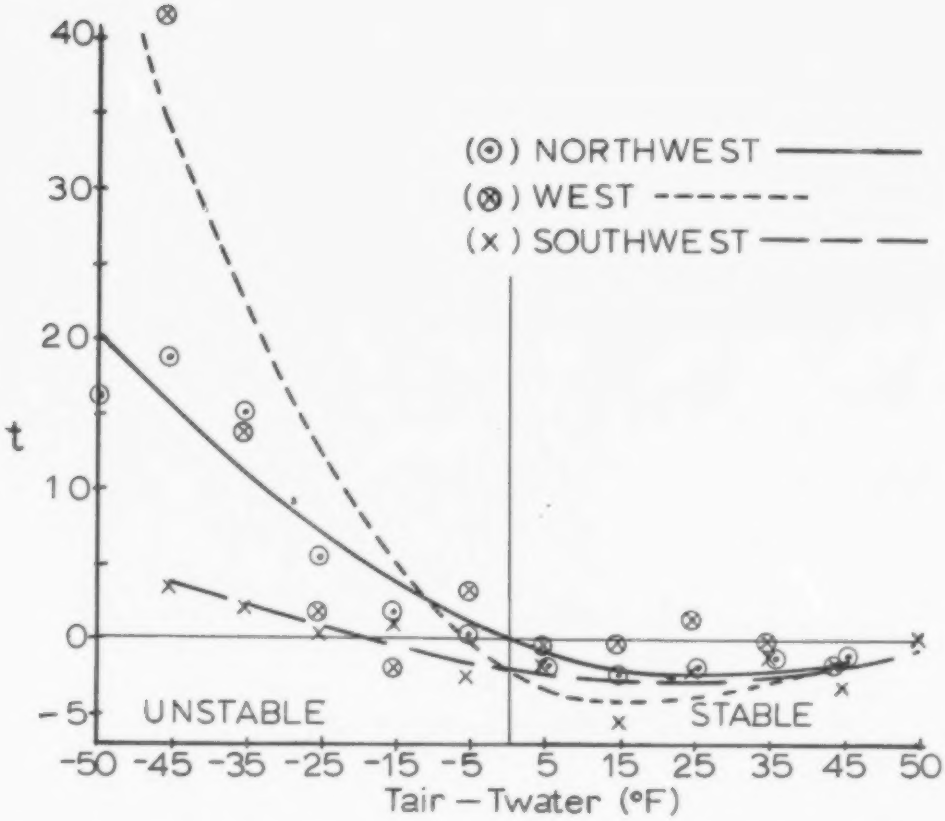


FIG. 5. Difference-of-means result (t) vs. air-water temperature difference ($T_{air}-T_{water}$) for overlake vs. overwater cloud cover changes; curves represent least squares quadratic relationship for each flow category.

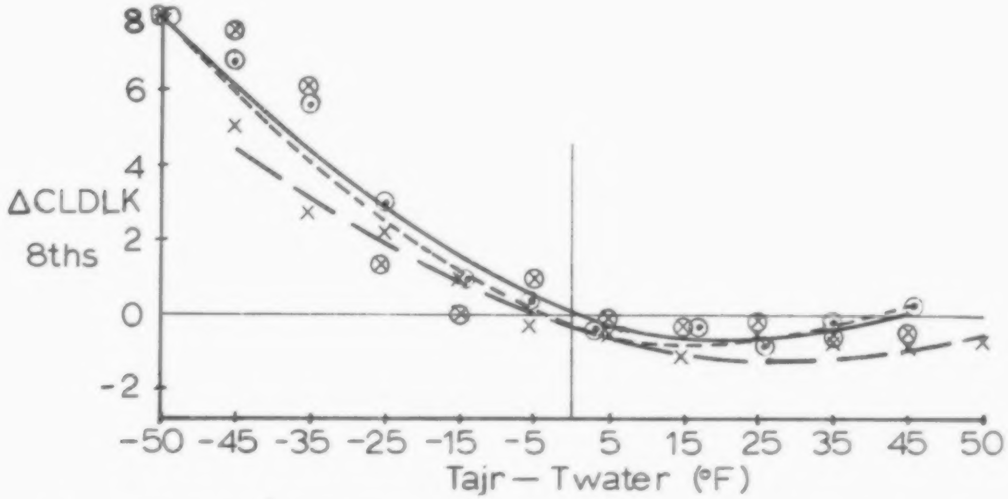


FIG. 6. Mean cloud cover change across Lake Michigan vs. air-water temperature difference ($T_{air}-T_{water}$); curves represent least squares quadratic relationship for each flow category.

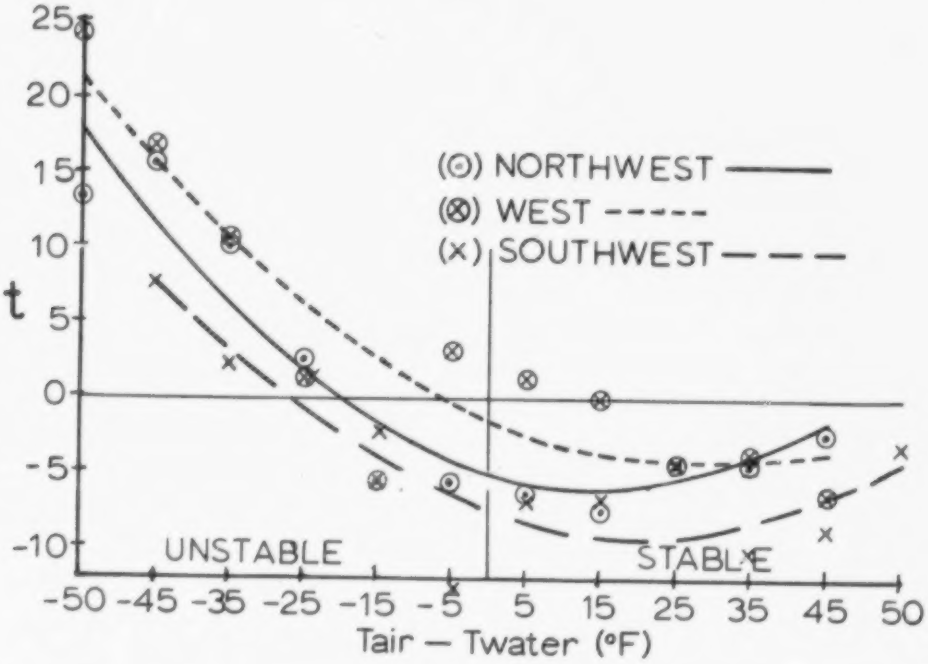


FIG. 7. Difference-of-means result (t) vs. air-water temperature difference ($T_{air}$-$T_{water}$) for overlake vs. overland temperature changes; curves represent least squares quadratic relationship for each flow category.

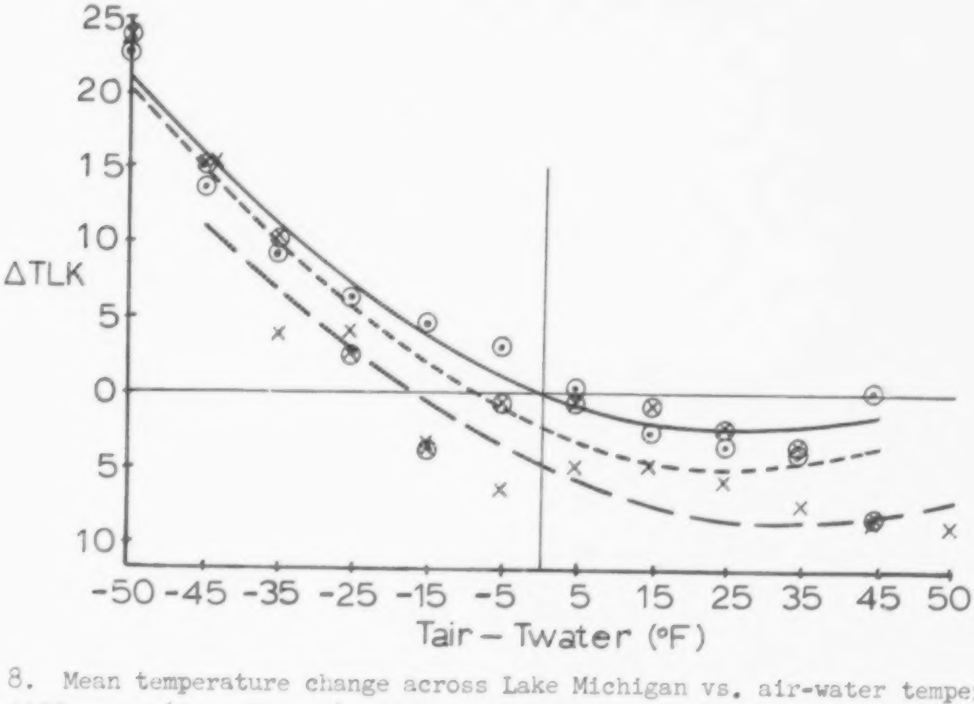


FIG. 8. Mean temperature change across Lake Michigan vs. air-water temperature difference ($T_{air}$-$T_{water}$); curves represent least squares quadratic relationship for each flow category.

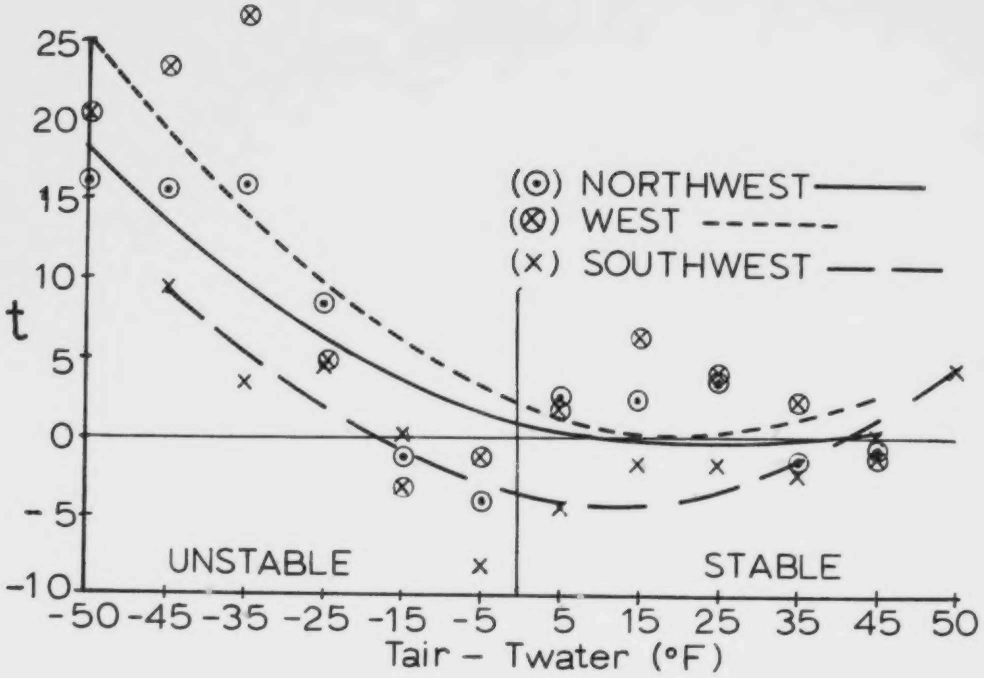


FIG. 9. Difference-of-means result (t) vs. air-water temperature difference ($T_{air}$-$T_{water}$) for overlake vs. overland dew point temperature changes; curves represent least squares quadratic relationship for each flow category.

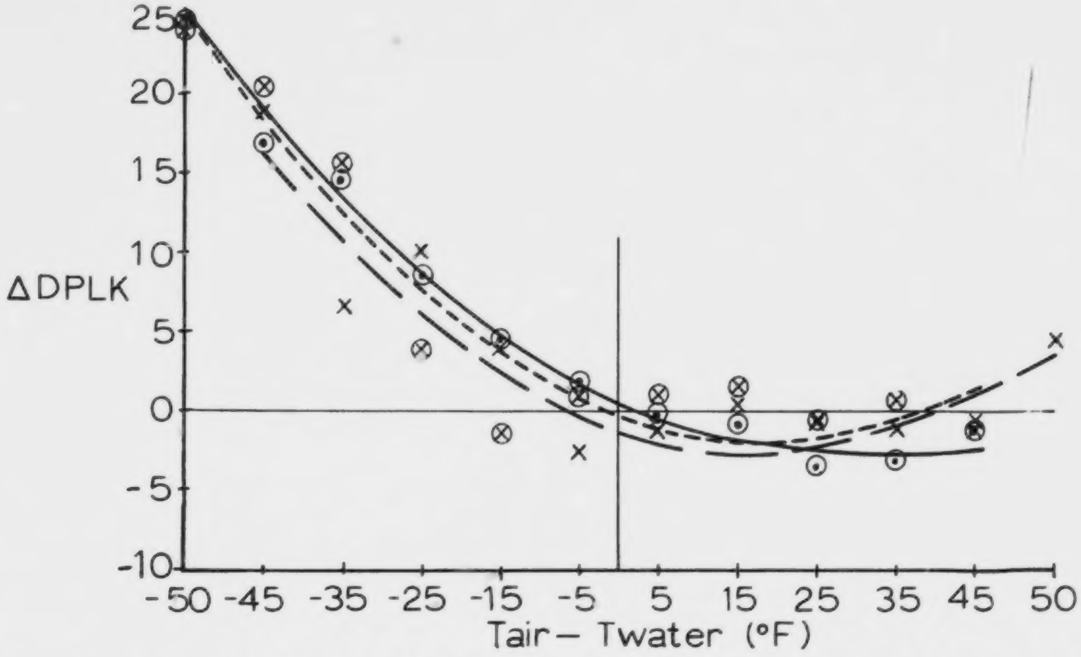


FIG. 10. Mean dew point temperature change across Lake Michigan vs. air-water temperature difference ($T_{air}$-$T_{water}$); curves represent least squares quadratic relationship for each flow category.

The "difference-of-means" test indicates a significant lake effect in cloud cover for the northwest and west flow categories when the water is more than 20°F warmer than the upwind air temperature (Fig. 5). The combined results for flows from these two general directions under the different stability categories are given in Table 1. The convective condensation levels (CCL's), also given for later calculations, are determined from the average surface temperature and dew point temperature values of each category. The total of the observations considered amounts to 18% of those considered in the first part of this study and 28% of the observations during the cold months of December through February.

TABLE 1. Combined results from west and northwest flows with calculated convective condensation levels (CCL's).

| $T_{air}-T_{water}$ (°F) | No. of Observ. | CLDLK (8ths) | Upwind Results | | | Downwind Results | | |
|---|---|---|---|---|---|---|---|---|
| | | | Temp (°F) | Dew Pt (°F) | CCL (M) | Temp (°F) | Dew Pt (°F) | CCL (M) |
| -50 | 51 | 8.0 | -16.5 | -28.3 | 800 | 5.4 | - 3.7 | 600 |
| -45 | 168 | 6.9 | - 6.7 | -17.5 | 740 | 7.4 | 0.5 | 450 |
| -35 | 221 | 5.9 | 1.2 | -10.7 | 800 | 11.1 | 4.0 | 400 |
| -25 | 178 | 2.2 | 14.3 | 4.5 | 700 | 18.9 | 11.1 | 500 |

The solar radiation, $Q(x)$, at a position $(x)$ over the lake can be related to cloudiness data by the following equation (Klein 1948):

$$Q(x) = Q_c\{1 - [1-k'(x)]C(x)\}$$

or

$$Q(x)/Q_c = 1 - K(x)C(x) \quad \text{where } K(x) = 1 - k'(x) \qquad (1)$$

Here $Q_c$ is the radiation with cloudless skies, $C(x)$ is the fraction of the sky covered by clouds, $k'(x)$ is the ratio of radiation with complete overcast ($C(x) = 1$) to radiation under cloudless skies, $Q_c$, $(x)$ is the distance from the upwind shore and $K(x)$ is radiation depletion.

In the present investigation, nearly clear skies are recorded at the upwind shore stations when the air was more than 20°F colder than the water and, therefore, the value of $Q(x)/Q_c$ is interpreted as the ratio of the radiation received at a position, $(x)$, on the lake to that received at the upwind station. The problem is to assign values to the parameters $C(x)$ (sky cover), and $K(x)$ (radiation depletion) with respect to distance, $(x)$, from the upwind shore for the stability categories used. It is not intended to describe exact models of these parameters but rather, on the basis of the results of this and other studies, resonable approximations.

## CALCULATION OF K(x) (RADIATION DEPLETION)

The variation of radiation depletion, K(x), across the lake with respect to stability categories is perhaps the most difficult to define since it depends on several factors: (1) the type of cloud, (2) the form of condensation (ice crystals or water droplets), (3) the vertical thickness of the clouds, and (4) the liquid water content. Hewson (1943) and Neuberger (1957) give values of K(x) as a function of liquid water content and cloud thickness for cumuliform clouds consisting of water droplets.

Other investigations, in most cases, describe clouds formed by the lake effect as cumuliform (Lenschow 1965). The form of condensation in these clouds depends on the minimum temperatures in the regions of the clouds. The nucleation threshold for the freezing of supercooled droplets is generally below -20°C and in most cases temperatures much below this are required (Fletcher 1962). Temperature profiles obtained by overlake airplane flights during cold arctic outbreaks (Lenschow 1965) indicate that the temperatures in the cloud regions are generally equal to or warmer than -20°C. Therefore, significant formation of ice crystals seems unlikely in the cumuliform clouds which develop due to the lake effect.

The vertical thickness of the clouds, which is necessary to determine K(x), is determined by considering height-distance relationships for both the tops and bases of the clouds. The height of the inversion, which is the primary control mechanism for vertical development, should increase from its initial upwind value when an air mass crosses a relatively warm lake. This can be attributed to the convection initiated by the flux of heat and moisture with a more rapid increase in height associated with the release of latent heat by condensation.

Lenschow's investigation is applicable to the present study; it included observations made by airplane flights at several levels between Milwaukee and Muskegon, in December 1964 and January 1965, during cold arctic outbreaks. The mid-lake water temperatures were about 40°F and the air flow during these flights was reported to be from west to northwest with upwind air temperature ranging from -15°F to 15°F. Certain temperature profiles from these flights coincide with the stability conditions considered in the present investigation and are, therefore, suitable analogs of height-distance variations of the inversion with respect to stability categories. In particular, it was found that the four categories under consideration could be related to particular days for which Lenschow reported observations, as follows:

| $T_{air}-T_{water}$ (°F) | Corresponding Date in Lenschow's Study |
|---|---|
| -25 | 18 December 1964 |
| -35 | 13 January 1965 |
| -45 | 14 January 1965 |
| -50 | 29 January 1965 |

On the basis of the reported temperature profiles for each of these days, the inversion or cloud top height-distance models are defined (Fig. 11) for each stability category. Straight line delineations are chosen to simplify calculations.

Height-distance models of the cloud bases, also necessary to determine thickness, are obtained from the convective condensation levels (CCL's) determined from temperature and dew point data of the present study (Table 1). The calculated heights of the upwind CCL's range from 700 to 800 m and the downwind CCL's from 400 to 600 m. Because the calculated CCL's do not follow a set pattern with respect to the stability categories and because the variations in height are not large, an average cloud base (CCL) of 800 m is used at the upwind shore with a linear decrease to 450 m on the downwind side. With the cloud base and cloud top designated for each stability category as a function of distance, the vertical thicknesses of the clouds over the lake are thus approximated (Fig. 11).

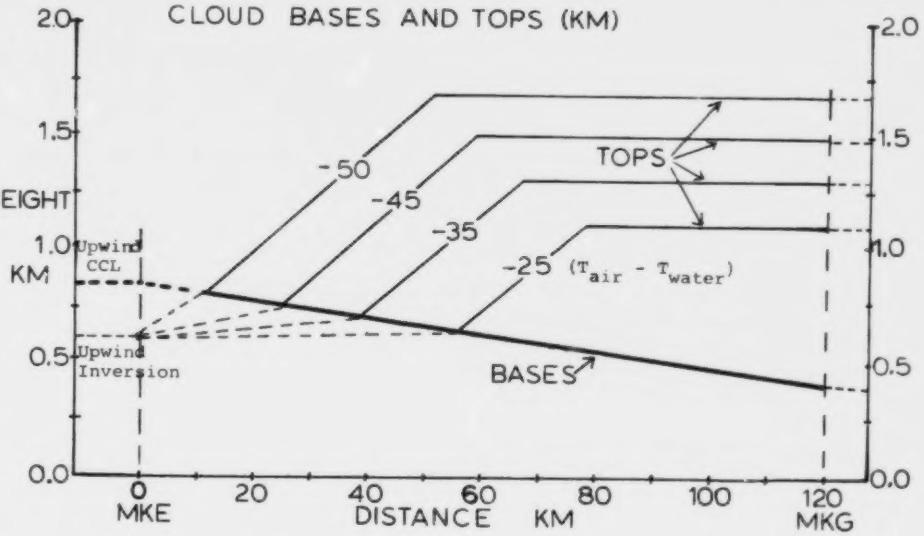


FIG. 11. Height-distance variation of cloud tops and bases across Lake Michigan with respect to air-water temperature difference categories (Tair-Twater).

The final parameter needed to determine K(x) is liquid water content in the clouds, W. The adiabatic liquid water content, $W_a$, is that which would condense from a parcel of air which, saturated at the cloud base, is lifted moist adiabatically to a given level, in this case the top of the cloud. Therefore, $W_a$ can be calculated with respect to distance across the lake by using the cloud bases and tops along with the horizontal air temperature distribution. Investigations of the ratio $W/W_a$ (observed to adiabatic values of liquid water content in clouds), indicate that the full adiabatic value is, perhaps, not realized in cumulus cloud (Warner and Squires 1958). However, it would be difficult to choose a particular value of the ratio $W/W_a$ since reported measurements are widely disparate. On the other hand, measured values of actual liquid water content, W, range from 0.3 to 1.0 $gm/m^3$ for cumuliform clouds (Fletcher 1962) with the lower values corresponding to the colder air temperatures. Since the values obtained from adiabatic content calculations in this study agree with this range, the values used are the calculated adiabatic values, $W_a$, for the liquid water content.

The changes in surface air temperatures across the lake should be related to the inversion changes, or cloud top changes, since both are results of surface heating. A reasonable relation, which agrees with air temperature distribution reported by Lenschow is shown in Fig. 12. The height-distance variation of the inversion and the corresponding horizontal air temperature variation are shown in Fig. 12(a) and (b), respectively.

This representation suggests that the temperature change is rapid off the upwind shore, but becomes less after the CCL is reached and is perhaps negligible downwind from the position where the inversion reaches a maximum. This is reasonable in view of the fact that heat is being added to a progressively deeper column with corresponding smaller changes in air temperature.

The adiabatic liquid water content values are determined from surface air temperature values in regions A, B, and C (Fig. 12) based on the known upwind and downwind temperature values, calculated as follows:

| Region | Temperature in Terms of Upwind, Downwind Values |
|---|---|
| A | Downwind |
| B | $\frac{\text{Upwind} + 3 \times \text{Downwind}}{4}$ |
| C | $\frac{\text{Upwind} + \text{Downwind}}{2}$ |

Adiabatic liquid water content, $W_a$, values corresponding to the above air temperature distribution and cloud thickness distributions (Figs. 12 and 11, respectively) are given in Fig. 13. The increase across the lake is due to downwind increases in both temperatures and cloud thickness values.

The liquid water content values in Fig. 13 along with the thickness values available from Fig. 11 and radiation depletion, K, from Fig. 14 (Hewson 1943) (Neuberger 1957) provide the necessary parameters to determine values of K(x). Figure 15 shows that the magnitudes of K(x), determined at 10-km increments across the lake, for the different stability categories are about the same toward the downwind shore. This convergence demonstrates the importance of considering variations in liquid water content between stability categories as well as variation in thickness. The convergence can be accounted for by con-

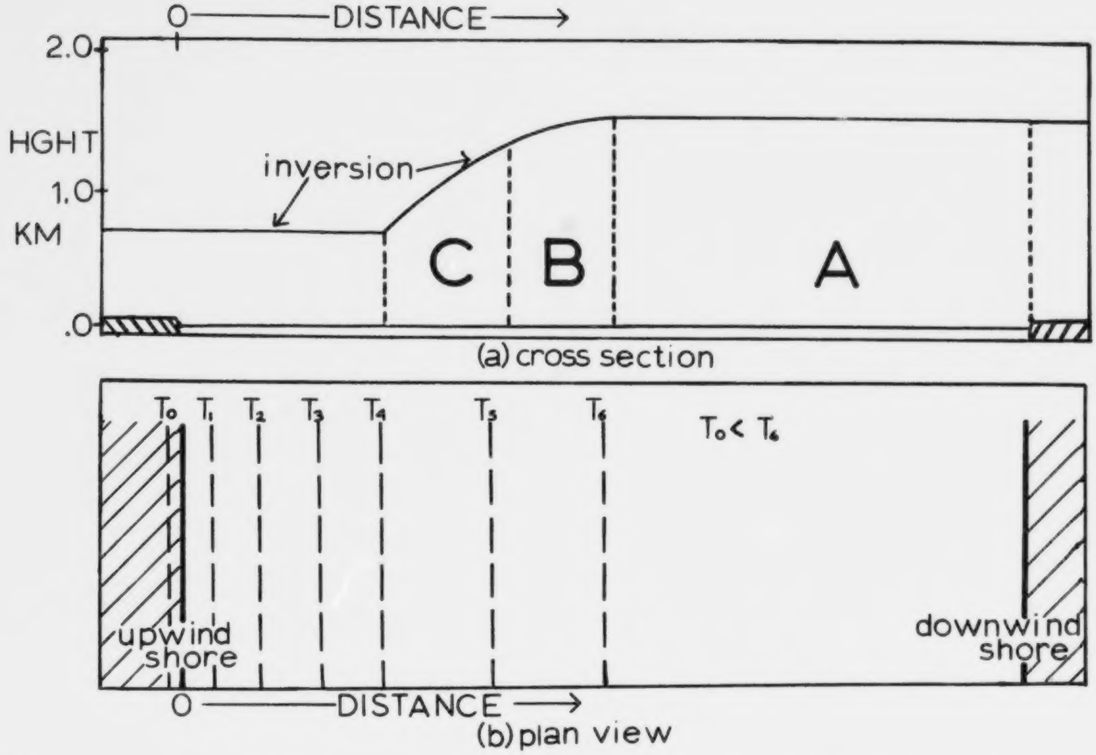

0
DISTANCE
2.0
HGHT
1.0
KM
.0
inversion
C
B
A
(a) cross section
$T_0$
$T_1$
$T_2$
$T_3$
$T_4$
$T_5$
$T_6$
$T_0 < T_6$
upwind shore
downwind shore
0
DISTANCE
(b) plan view

FIG. 12. Relationship between (a) height-distance variation of inversion, and (b) horizontal temperature distribution across Lake Michigan when relatively cold air crosses warm lake.

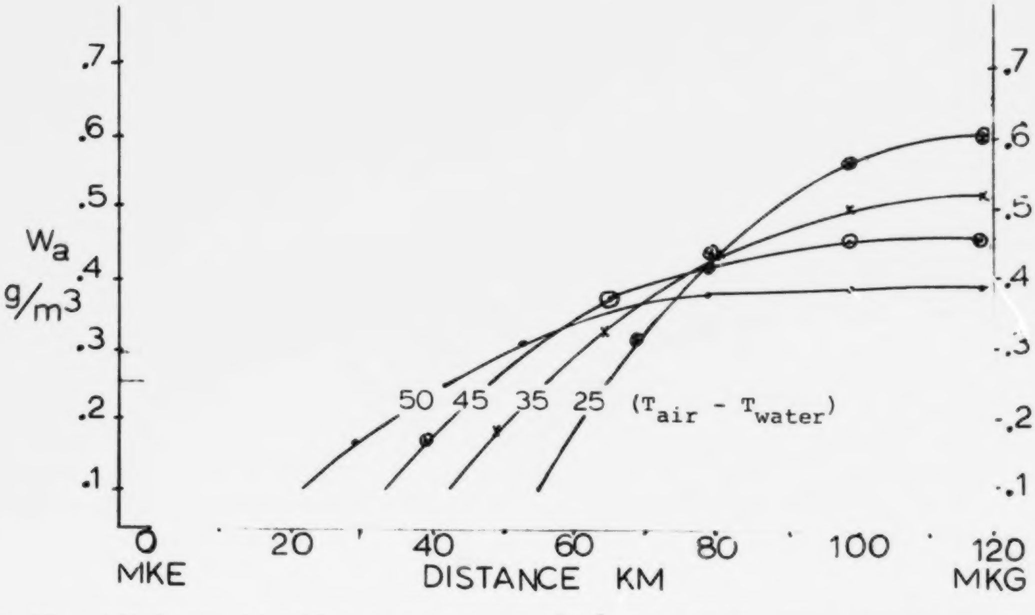


FIG. 13. Adiabatic liquid water content, ($W_a$), vs. air-water temperature difference ($T_{air}$-$T_{water}$) and distance across the lake; based on Figs. 11 and 12.

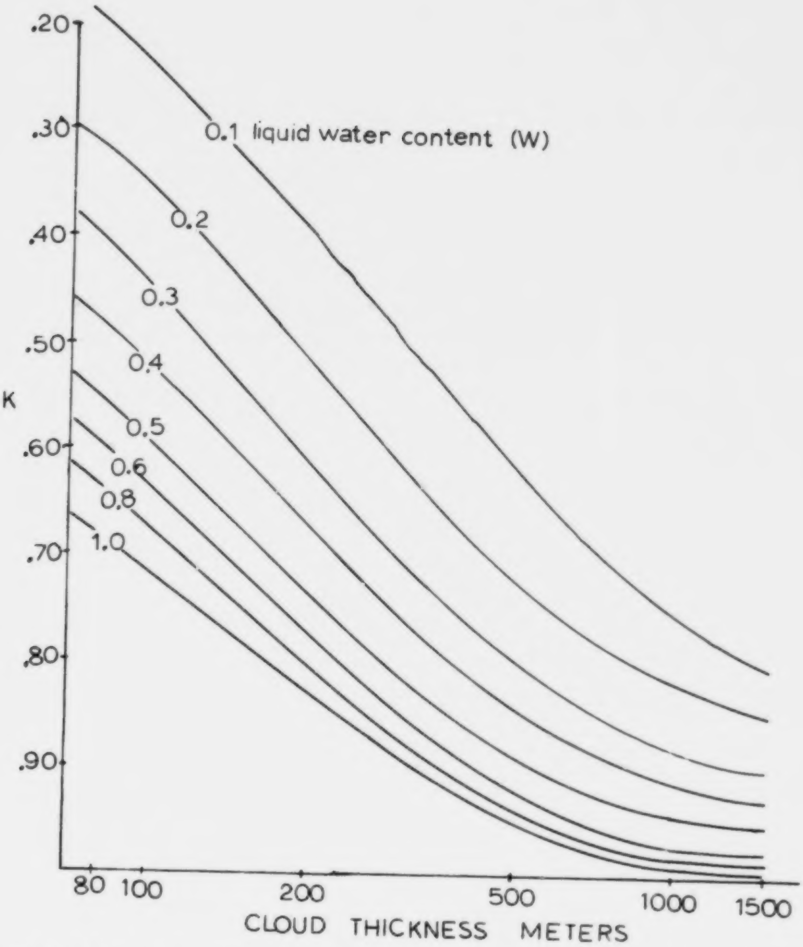


FIG. 14. Radiation depletion (K) vs. liquid water content (Wa) and cloud thickness; after Hewson 1943 and Neuberger 1957.

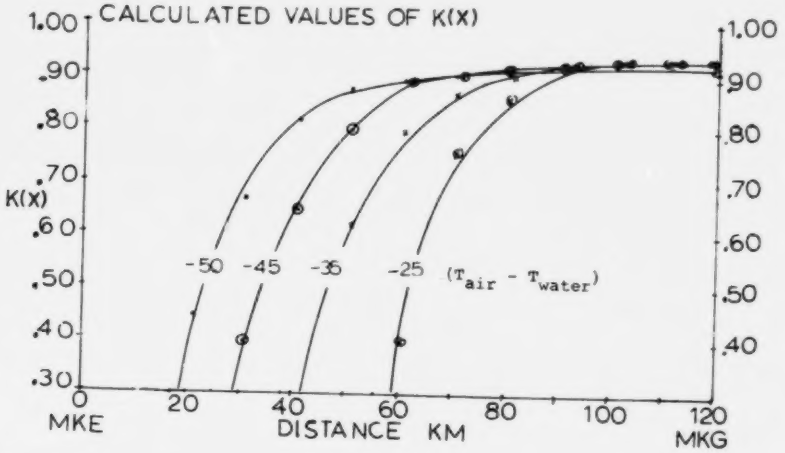


FIG. 15. Radiation depletion, K vs. distance across Lake Michigan determined from liquid water content and thickness values of Figs. 13 and 11, respectively.

sidering the behavior of the changes in vertical thickness and liquid water content in the different stability cases, i.e., the relative thickness is inversely proportional to stability (Fig. 11) while the relative magnitudes of liquid water content are directly proportional to stability (Fig. 13).

## CALCULATION OF C'(x) (AMOUNT OF SKY COVERED BY CLOUDS)

The final parameter needed to calculate incident solar radiation is the amount of cloud cover at any location, C(x). Since the sky is assumed to be clear at the upwind shore, the cloud cover over a given location on the lake, C(x), can be defined as a fraction, C'(x), of the observed ratio of the cross-lake cloud change, ΔCLDLK/8, (ΔCLDLK is given in Table 1) as follows:

$$C(x) = C'(x) \times \Delta CLDLK/8 .$$

Since ΔCLDLK is a function of stability, C'(x) should also be related to the stability as well as distance (x) from the upwind shore. The problem at this stage of the study is to select values of C'(x) with respect to stability and downwind distance. Models for C'(x) can be proposed by considering the following:

1. C'(x) will be 0 at the upwind shore and will become 1.0 before or over the downwind shore.

2. The location, (x), where C'(x) becomes greater than zero, i.e., beginning of cloud development, should correspond to the intersection of the cloud base and top lines (Fig. 11).

3. The location, (x), where C'(x) becomes 1.0, i.e., where observed downwind shore amount of cloud cover is attained, should be downwind from the location where the cloud tops become maximum (Fig. 11) since the clouds should start to spread out beyond this point.

On the basis of 3 above, it is perhaps best to present three alternatives: C'(x) becoming 1.0 at (a) the downwind shore, (b) midway between the location where the inversion becomes a maximum and the downwind shore, and (c) the location where the inversion becomes maximum.

Figure 16 shows overlake values of C'(x) with respect to stability categories and correspond to the alternatives (a), (b), and (c), respectively. On the basis of 2 above, the location where C'(x) for a given stability category becomes greater than zero is the same in all three figures.

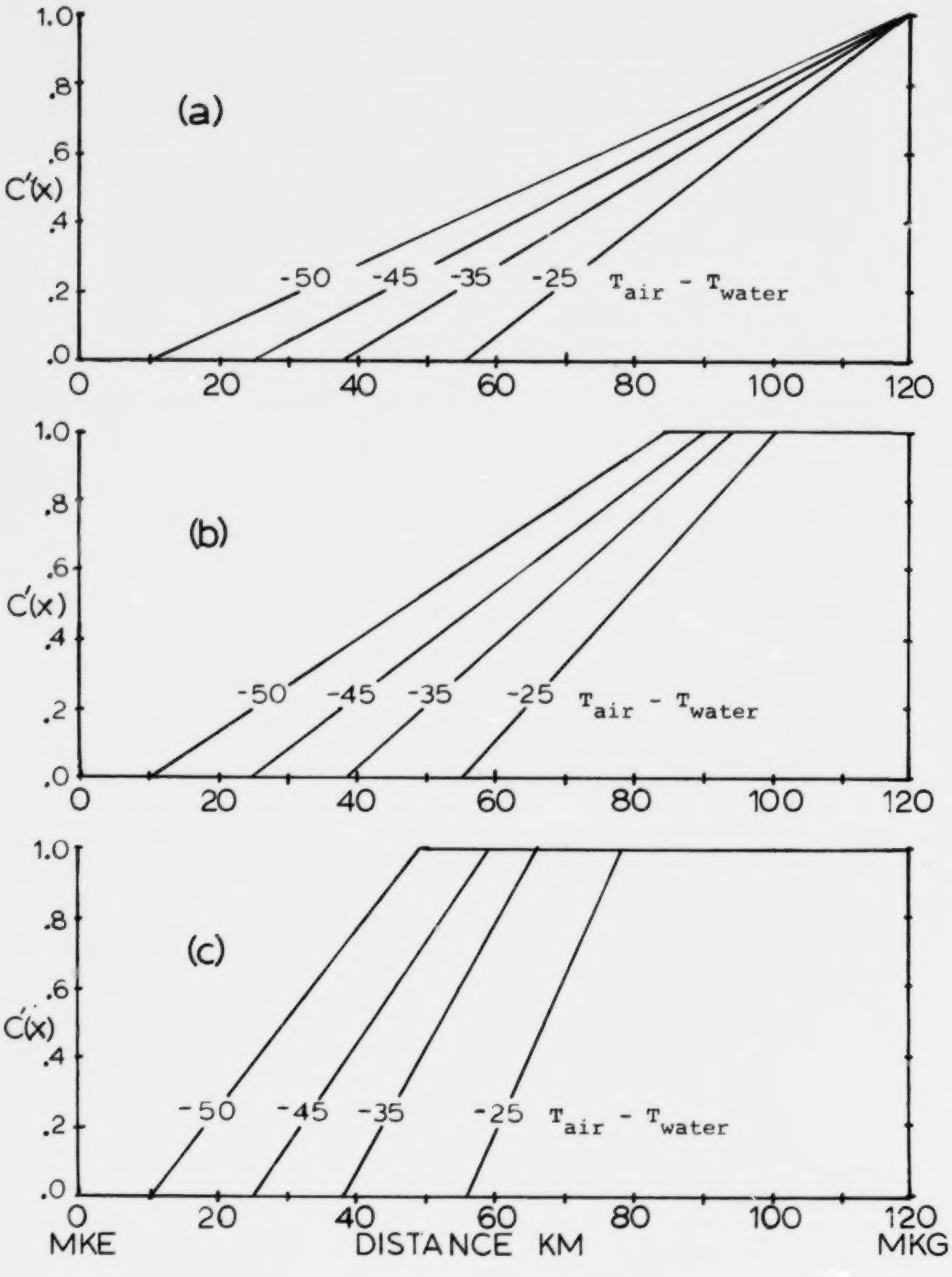


FIG. 16. Three alternatives for C'(x) models: (a) maximum cloudiness attained at downwind shore, (b) maximum cloudiness attained midway between location where inversion reaches a maximum and downwind shore, and (c) maximum cloudiness attained at location where inversion reaches a maximum.

## RESULTS OF RADIATION INVESTIGATION

It is now possible to calculate values of $Q(x)/Q_c$ with respect to distance across the lake and stability by using selected models of $K(x)$ and $C'(x)$ and the cloud change values from Table 1. Since $C(x) = C'(x)\ \Delta CLDLK/8$, $Q(x)/Q_c$ can be obtained directly by using the $C'(x)$ values of Fig. 13 in Eq. (2) (same as Eq. (1) with substitution $C(x) = C'(x)\ \Delta CLDLD/8$)

$$Q(x)/Q_c = 1 - K(x)C'(x)\Delta CLDLK/8 \qquad (2)$$

Figure 17(a), (b), (c) gives $Q(x)/Q_c$ values calculated at 10-km increments across the lake and correspond to the $C'(x)$ selections of Figure 16(a), (b), (c), respectively.

Further resolution of these values is perhaps desirable to make them more useful for biological investigations. A reasonable resolution would be to represent these results with respect to the western, middle and eastern thirds of the lake, corresponding to distance intervals, 0-40, 40-80, and 80-120 km, respectively.

The averages or arithmetic means of $Q(x)/Q_c$ over each subdivision with respect to the stability categories are calculated using the interpolated values of $Q(x)/Q_c$ at the midpoints of the 10-km increments. The results of these calculations are summarized in Table 2.

TABLE 2. $Q(x)/Q_c$ values averaged over three subdivisions of Lake Michigan with respect to $T_{air}-T_{water}$.

| $T_{air}-T_{water}$ (°F) | C'(x) Selections Represented in Fig. 16 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (a) | | | (b) | | | (c) | | |
| | West | Middle | East | West | Middle | East | West | Middle | East |
| -50 | .93 | .60 | .25 | .90 | .41 | .09 | .84 | .14 | .08 |
| -45 | .98 | .72 | .37 | .98 | .60 | .22 | .95 | .35 | .20 |
| -35 | 1.00 | .84 | .48 | 1.00 | .75 | .33 | 1.00 | .56 | .31 |
| -25 | 1.00 | .97 | .82 | 1.00 | .96 | .78 | 1.00 | .93 | .74 |

Up to this point, calculations have been made for each $C'(x)$ alternative, as given by Fig. 16, as though they were all equally reasonable. However, observations from research ships and commercial vessels on Lake Michigan indicate that the cloud cover over the downwind shore also extends a distance upwind. This suggests that the $C'(x)$ alternative in Fig. 16(a) (maximum cloud cover attained at the downwind shore) is, perhaps, less likely than those represented by Figs. 16(b) and 16(c). The western, middle and eastern subdivision aver-

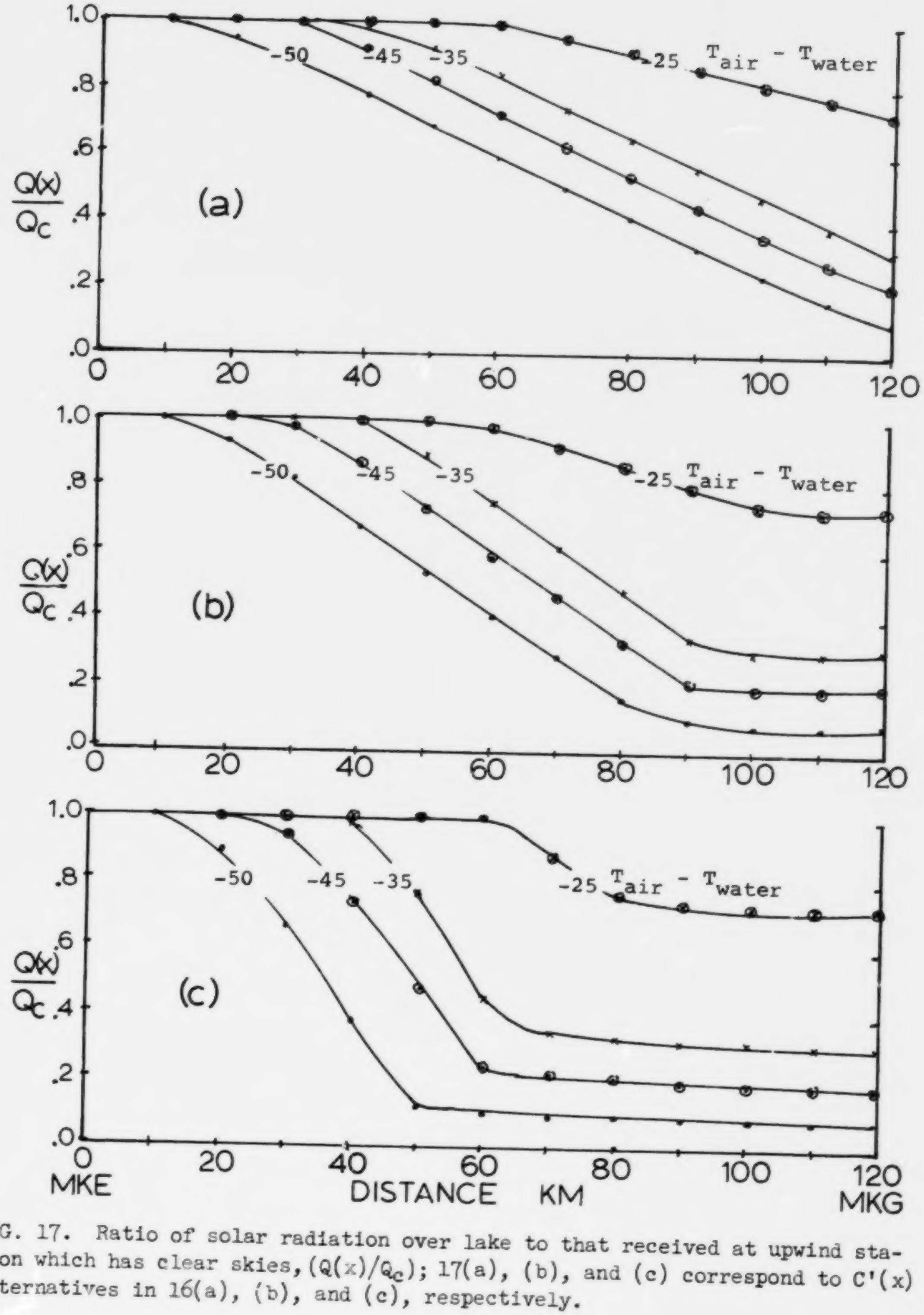


FIG. 17. Ratio of solar radiation over lake to that received at upwind station which has clear skies, $(Q(x)/Q_c)$; 17(a), (b), and (c) correspond to $C'(x)$ alternatives in 16(a), (b), and (c), respectively.

ages of $Q(x)/Q_c$ corresponding to cases (b) and (c) are presented together in Fig. 18 where they appear on the same scale and, therefore, can be compared with respect to subdivision and stability.

Figure 18 shows that the case (b) values of $Q(x)/Q_c$ average out to be always greater than or equal to the corresponding case (c) values. This relationship can be used to define values with upper and lower limits which can be used in implementing these results.

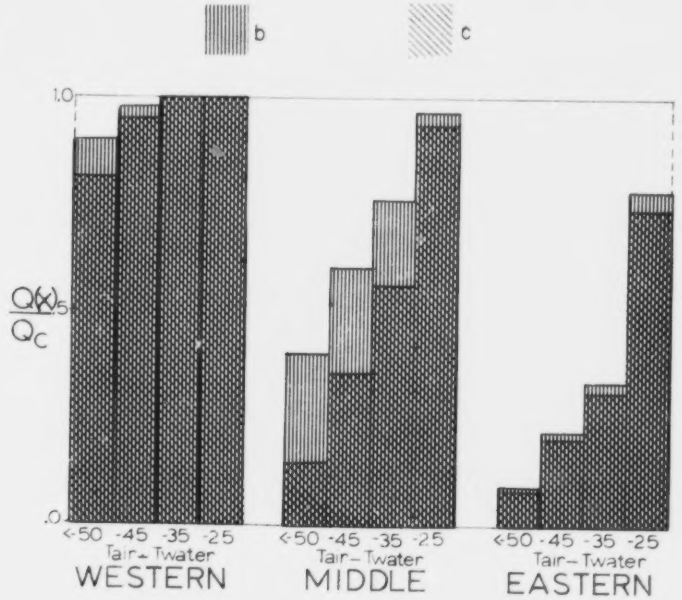


FIG. 18. Average ratio of solar radiation over the western, middle and eastern one-thirds of Lake Michigan to that received at upwind shore station ($Q(x)/Q_c$) corresponding to $C'(x)$ alternatives given in Fig. 16(b) and (c).

## SUMMARY AND CONCLUSIONS

A method for analyzing cloud cover, temperature and dew point temperature changes across Lake Michigan has been described. This method utilizes readily available climatological data and includes provisions for considering stability, direction of air flow and non-lake influences. Results obtained by applying this method to one year of data indicate that due to the lake's effect:

1. Cloud cover in an air mass which is initially at least 20°F colder than the water will increase as it crosses the lake. The amount of change is proportional to the degree of instability and can be summarized as follows:

If clear skies prevail over the upwind shore of the lake, the corresponding cloud cover over the downwind shore will be

(a) overcast if the air is more than 50°F colder than the water

(b) broken (6/8) if the air is from 30°F to 50°F colder than the water

(c) scattered (3/8) if the air is from 20°F to 30°F colder than the water

2. Flow from the southwest will, in the mean, result in less sky cover change than with flow from west or northwest with the same air-water temperature difference.

3. Air temperature and dew point temperature changes across the lake are between 1/3 and 1/2 the corresponding air-water temperature difference when the air is colder than the water.

4. An air mass which is initially the same temperature or warmer than the water has little change in cloud cover, temperatures or dew points.

Utilizing the above results and conclusions, changes in incident solar radiation across the lake have been described. A summary of the radiation results averaged over western middle and eastern thirds of the lake given in Table 3 (a résumé of Fig. 18), lists values of the incident solar radiation to clear sky radiation over the western, middle and eastern thirds of Lake Michigan as functions of stability ($T_{air}$ - $T_{water}$). The characteristic values in Table 3 correspond to the average and the upper and lower limits defined by the case (b) and case (c) values, respectively.

TABLE 3. Ratio, $Q(x)/Q_c$, of incident solar radiation to clear sky radiation in the western, central and eastern thirds of Lake Michigan as a function of stability.

| Tair-Twater | Western 1/3 | Middle 1/3 | Eastern 1/3 |
|---|---|---|---|
| -50 | .86 ± .04 | .28 ± .13 | .09 ± .01 |
| -45 | .96 ± .01 | .48 ± .12 | .21 ± .02 |
| -35 | 1.00 ± .00 | .66 ± .09 | .32 ± .01 |
| -25 | 1.00 ± .00 | .95 ± .01 | .76 ± .02 |

Ranges in Table 3 vary between the subdivisions, with relatively large ranges corresponding to the middle one-third and small and perhaps negligible ranges for western and eastern one-thirds. The small ranges for the western and eastern portions are probably favorable results, since in these regions of relatively shallow water light is more apt to penetrate to the bottom and hence influence the entire population present.

It is concluded that observations from land stations supported by a few observations from ships on the lake can be used to make reasonable and useful estimations of cloud conditions and incident solar radiation over Lake Michigan.

## REFERENCES

FLETCHER, N. H. 1962. The physics of rain clouds. Cambridge University Press, Cambridge, England, 386 p.

GEORGE, J. J. 1940. On distortion of stream fields by small heat sources. Monthly Weather Review, 68(3): 63-66.

HEWSON, E. W. 1943. The reflection, absorption and transmission of solar radiation by fog and clouds. Quart. J. Roy. Meteor. Soc., 69(298): 47-62.

KLEIN, N. H. 1948. Calculations of solar radiation and the solar heat on man. J. Meteorology, 5(4): 119-129.

LENSCHOW, D. H. 1965. Airborne measurements of atmospheric boundary layer structure. Atmospheric Boundary Layer Studies, U. W. Final Report 1965, University of Wisconsin Department of Meteorology, p. 146-209.

NEUBERGER, H. 1957. Introduction to physical meteorology. The Pennsylvania State University, University Park, Pa., 271 p.

PANOFSKY, H. A. and Glenn W. Brier. 1958. Some applications of statistics to meteorology. Pennsylvania State University, University Park, Pa., 224 p.

U. S. Weather Bureau. 1959. Climatology and Weather Services of the St. Lawrence Seaway and Great Lakes. USWB Tech. Paper No. 35.

__________. 1964. Local climatological data with comparative data, 1963, Madison, Wisconsin. USCOMM-WB-Ashville, N. C.

WARNER, J. and P. Squires. 1958. Liquid water content and the adiabatic model of cumulus development. Tellus, 10(3): 390-394.

# APPENDIX 1

## THE "DIFFERENCE OF MEANS" TEST

The "difference of means" test is designed to determine whether real differences exist between two sets of similar data. It gives the probabalistic value of a hypothetical, infinite, normally distributed population which would yield two independent samples with size $N_1$ and $N_2$, means $\overline{X_1}$ and $\overline{X_2}$, and variances $V_1$ and $V_2$. These variables determine the ratio:

$$t = \frac{\overline{X_1} - \overline{X_2}}{\left[\dfrac{N_1V_1 + N_2V_2}{N_1 + N_2 - 2} \times \dfrac{1/N_1 + 1/N_2}{1}\right]^{1/2}}$$

If assumptions of normality, independence, and equality of variances are valid, this ratio is distributed as the "t" distribution, and to test the hypothesis $\overline{X_1} = \overline{X_2}$ it is merely necessary to use a "t" distribution table.

In this study, the sets of data tested are the overlake changes and the overland changes, which will be denoted as $\overline{\Delta LK}$ and $\overline{\Delta LD}$, respectively. Also, since the overland and overwater comparisons are coincident, the samples are of the same size as $N_1 = N_2$. Substituting a common N into the relation above and replacing $\overline{X_1}$ and $\overline{X_2}$ by $\overline{\Delta LK}$ and $\overline{\Delta LD}$, respectively, the following expression is obtained, which is identical to that on page 275 of the report:

$$t = \frac{\overline{\Delta LK} - \overline{\Delta LD}}{\left[\dfrac{VR\Delta LK + VR\Delta LD}{N - 1}\right]^{1/2}}$$

## APPENDIX 2

TABLE A. Number of observations and distributions of results.

| Air-water temperature difference | December 1962 - November 1963 | | | | | |
|---|---|---|---|---|---|---|
| | Northwest | | West | | Southwest | |
| | No. of obsv. per interv. | Degrees of freedom | No. of obsv. per interv. | Degrees of freedom | No. of obsv. per interv. | Degrees of freedom |
| <-50°F | 39 | 76 | 12 | 22 | 0 | 0 |
| -50 to -40 | 120 | 238 | 48 | 94 | 10 | 18 |
| -40 to -30 | 130 | 258 | 91 | 180 | 23 | 44 |
| -30 to -20 | 101 | 200 | 77 | 152 | 10 | 18 |
| -20 to -10 | 117 | 232 | 86 | 170 | 18 | 34 |
| -10 to 0 | 232 | 462 | 130 | 258 | 126 | 250 |
| 0 to +10 | 249 | 496 | 211 | 420 | 274 | 546 |
| +10 to +20 | 216 | 430 | 200 | 398 | 289 | 576 |
| +20 to +30 | 123 | 244 | 163 | 324 | 149 | 296 |
| +30 to +40 | 49 | 96 | 55 | 108 | 136 | 270 |
| +40 to +50 | 15 | 28 | 19 | 36 | 61 | 120 |
| >+50 | 0 | 0 | --- | --- | 8 | 14 |
| Totals | 1392 | | 1092 | | 1104 | |

TABLE B. Summary of cloud, temperature, and dew point results.

| Air-water temperature difference | Degrees of freedom | Temperature | | | Dew point | | | Cloud cover | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $\overline{\Delta TLD}$ | $\overline{\Delta TLK}$ | "t" Score | $\overline{\Delta DPLD}$ | $\overline{\Delta DPLK}$ | "t" Score | $\overline{\Delta CLDLD}$ | $\overline{\Delta CLDLK}$ | "t" Score |
| Southwest flow | | | | | | | | | | |
| -50°F | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -50 to -40 | 18 | 3.00 | 15.20 | 8.15 | 3.20 | 18.90 | 9.26 | -0.10 | 5.10 | 3.44 |
| -40 to -30 | 44 | 1.35 | 3.83 | 2.18 | 1.78 | 6.48 | 3.28 | 0.26 | 2.61 | 2.03 |
| -30 to -20 | 18 | 2.10 | 3.90 | 1.16 | 1.20 | 10.00 | 4.58 | 2.20 | 2.40 | 0.18 |
| -20 to -10 | 34 | -1.00 | -3.86 | -1.99 | 1.00 | 3.57 | 0.65 | -1.57 | 1.00 | 1.10 |
| -10 to 0 | 250 | 0.99 | -6.45 | -13.58 | 1.68 | -2.79 | -8.01 | 0.80 | -0.25 | -2.72 |
| 0 to +10 | 540 | -1.63 | -4.93 | -7.00 | 0.56 | -1.25 | -4.85 | 0.18 | -0.33 | -1.94 |
| +10 to +20 | 576 | -2.54 | -4.93 | -6.80 | 0.55 | 0.12 | -1.25 | 0.32 | -1.06 | -5.49 |
| +20 to +30 | 296 | -2.83 | -5.50 | -5.01 | -0.04 | -0.82 | -1.57 | -0.01 | -0.50 | -1.64 |
| +30 to +40 | 270 | -0.31 | -7.20 | -11.26 | 0.70 | -1.05 | -2.50 | -0.30 | -0.64 | -1.11 |
| +40 to +50 | 120 | -0.89 | -8.31 | -8.94 | -0.72 | -0.48 | 0.31 | -0.49 | -1.57 | -3.48 |
| +50 | 14 | 0.38 | -9.00 | -3.13 | -2.88 | 4.75 | 4.14 | -1.25 | -0.88 | 0.42 |
| Northwest flow | | | | | | | | | | |
| -50°F | 76 | 9.43 | 22.69 | 12.90 | 8.10 | 24.72 | 16.01 | 1.15 | 8.00 | 16.37 |
| -50 to -40 | 238 | 4.93 | 13.74 | 15.51 | 5.08 | 16.94 | 15.64 | 0.62 | 6.49 | 18.52 |
| -40 to -30 | 258 | 4.63 | 9.65 | 11.28 | 3.28 | 14.36 | 15.43 | 0.89 | 5.82 | 15.44 |
| -30 to -20 | 200 | 5.03 | 6.24 | 2.78 | 3.11 | 8.68 | 8.21 | 0.55 | 2.98 | 5.02 |
| -20 to -10 | 232 | 7.68 | 4.73 | -5.73 | 5.15 | 4.56 | -1.09 | 0.18 | 0.79 | 1.76 |
| -10 to 0 | 462 | 5.37 | 3.07 | -5.83 | 3.11 | 1.76 | -3.95 | 0.56 | 0.59 | 0.11 |
| 0 to +10 | 496 | 3.99 | 0.28 | -6.82 | 0.74 | -0.51 | -2.36 | 0.11 | -0.41 | -1.91 |
| +10 to +20 | 430 | 1.66 | -2.24 | -7.24 | -2.35 | -0.99 | 2.34 | 0.30 | -0.43 | -2.74 |
| +20 to +30 | 244 | -0.80 | -3.85 | -4.44 | -6.37 | -3.47 | 3.18 | -0.30 | -0.93 | -1.81 |
| +30 to +40 | 96 | 2.33 | -4.02 | -4.66 | -0.98 | -3.04 | -1.37 | 0.59 | -0.10 | -1.41 |
| +40 to +50 | 28 | 3.33 | 0.20 | -2.10 | -0.67 | -1.87 | -0.54 | 2.07 | 0.27 | -1.66 |
| +50 | 0 | | | | | | | | | |
| West flow | | | | | | | | | | |
| -50°F | 22 | 1.25 | 23.17 | 24.70 | -1.50 | 24.08 | 20.00 | 0.00 | 8.00 | ∞ |
| -50 to -40 | 94 | 2.73 | 15.17 | 16.56 | 0.38 | 20.42 | 23.56 | -0.21 | 7.88 | 42.10 |
| -40 to -30 | 180 | 0.40 | 10.33 | 10.77 | 0.15 | 15.47 | 26.40 | -0.45 | 6.08 | 13.80 |
| -30 to -20 | 152 | 0.70 | 2.39 | 1.88 | -0.92 | 3.91 | 4.76 | -0.03 | 1.23 | 1.68 |
| -20 to -10 | 170 | 1.20 | -3.86 | -6.40 | 0.71 | -1.48 | -3.04 | 1.03 | -0.09 | -1.61 |
| -10 to 0 | 258 | -2.75 | -0.69 | 3.16 | 1.23 | 0.70 | -1.15 | -0.25 | 1.04 | 3.44 |
| 0 to +10 | 420 | -1.72 | -0.50 | 1.94 | -0.23 | 0.62 | 1.58 | 0.00 | -0.13 | -0.46 |
| +10 to +20 | 398 | -0.86 | -0.67 | 0.25 | -1.84 | 1.35 | 6.34 | -0.15 | -0.16 | -0.03 |
| +20 to +30 | 324 | 1.36 | -2.29 | -4.22 | -3.01 | -0.71 | 3.98 | -0.45 | -0.01 | 1.53 |
| +30 to +40 | 108 | 2.84 | -3.60 | -4.06 | -2.35 | 0.34 | 2.24 | -0.55 | -0.51 | 0.08 |
| +40 to +50 | 36 | 7.37 | -8.32 | -6.70 | 1.89 | -1.11 | 1.08 | 0.00 | -0.58 | -0.89 |
| +50 | 0 | | | | | | | | | |

# METEOROLOGICAL DATA ACQUISITION SYSTEM

Floyd C. Elder, H. K. Soo, and John C. Dute

Abstract. A meteorological data acquisition system has been designed for use aboard the research vessels of the Great Lakes Research Division of The University of Michigan. The system employs a digital millivolt recorder having a minimum full-scale range of 10 millivolts and a resolution of 10 microvolts. The data are recorded on punched paper tape in a computer compatible code. The sensor system makes possible the measurement of wind speed, air temperature, dew point temperature, water temperature, and four components of the radiation balance from aboard the research vessels.

## INTRODUCTION

The need for accurate meteorological measurements over the Great Lakes has long been recognized. Studies of energy balance, evaporation, or momentum transfer require knowledge of the temperature, wind, and moisture structure over the lake surface. In most cases, such studies must rely upon measurements made at stations surrounding the lakes while making adjustments believed to compensate for a lake-land difference. The work of Bruce and Rodgers (1962) and that of Platzman (1965) are typical examples. However, Bellaire (1963) has shown that in many cases shore-measured winds were unreliable as indicators of winds over the lake. Jacobs (1965) found that the wind measured at Muskegon during light wind conditions showed only a small correlation to ship-measured winds and, in fact, does not show significant relation to wind measured at the U.S. Lake Survey Research Tower located only 5 miles distant and 1 mile off shore.

To provide a body of meteorological data over Lake Michigan, a program to instrument research vessels operated by the Great Lakes Research Division was begun in 1963. The goal was to provide each ship with a sensor and recorder system such that comprehensive measurement of the meteorological variables would be recorded automatically at frequent intervals whenever the ship was operating on the lake.

The volume of information required to document the meteorological conditions over large areas of the lake makes computer data processing highly desirable. A recording system providing an output format and data storage in a form compatible with computer processing was, therefore, chosen. Consideration of reliability and cost led to a choice of punched paper tape as the recording medium.

Choice of the recorder system was influenced also by a desire that the system have a high degree of versatility. One recorder must record the data from several sensors having a range of characteristics. The number and type of sensors are, furthermore, subject to change as research programs develop or change emphasis.

Consideration of these factors led to the choice of a basic millivolt recording system with option to record up to 20 input variables. Recording is in terms of voltage with scaling of each variable, and conversion into engineering units accomplished during computer reduction of the data.

## RECORDING SYSTEM

The recording system scans and digitally records the differential voltage output of up to twenty analog sensors in a single data sequence (hereafter called data frame). The voltage resolution of the system is 10 μv and the minimum signal for full scale indication is 10 mv. All data are displayed and recorded in a three digit with sign format on 8-level punched paper tape.

Frequency of recording sequence may be selected as once per minute, 10 times per hour, or stand-by (for calibration purposes). In addition to the sensor data, identifying information is recorded at the beginning of each data frame. This includes four digits of time to the nearest minute, a three-digit selectable identification number, and an appropriate format indicator so that the tape reader of the computer can locate the beginning of each frame. The sensor data is also displayed as it is recorded so the operator can monitor a single channel during recording or calibration. The clock time base is obtained from an internal oscillator which has an accuracy of 0.05%, thus, the frequency stability of the prime power source is not critical.

By means of front panel controls (Fig. 1), the operator may choose which data channels he wishes to record or omit, or he may choose to record zeros for those sensors out of use, thus making it unnecessary to change the data format at a later time. Each channel has an individual attenuator which enables convenient scaling of each input variable. The modular construction of the recording system makes it possible to expand it, increase the number of channels, or to include other types of information, such as pulse rate signals which are produced by some types of anemometers.

### FUNCTIONAL DESCRIPTION OF RECORDING SYSTEM

Figure 2 is a functional block diagram of the entire recording system. In this paper, only the functional operation of the system is discussed. While it is frequently easier to understand the operation of a system by starting from

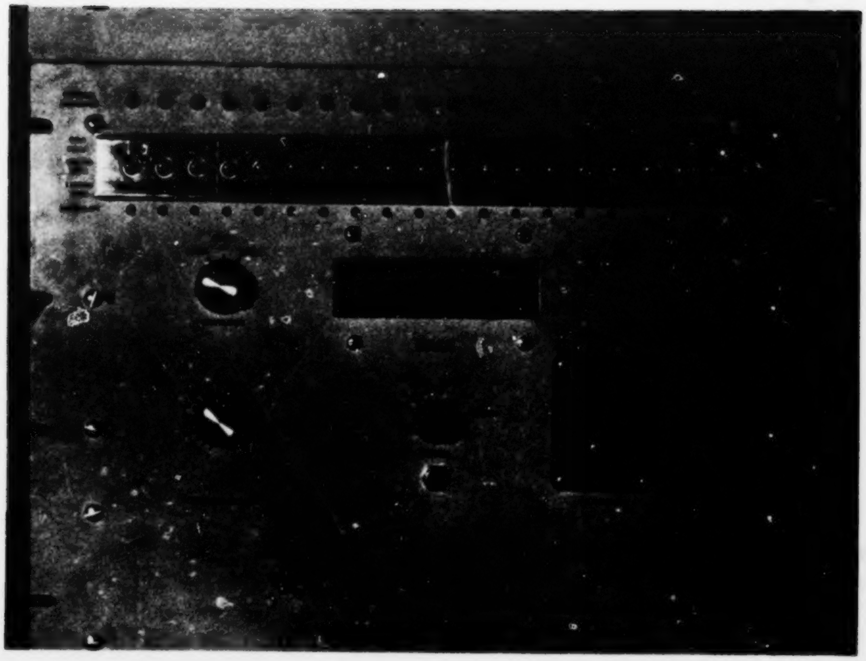


FIG. 1. Control panel of digital recording system.

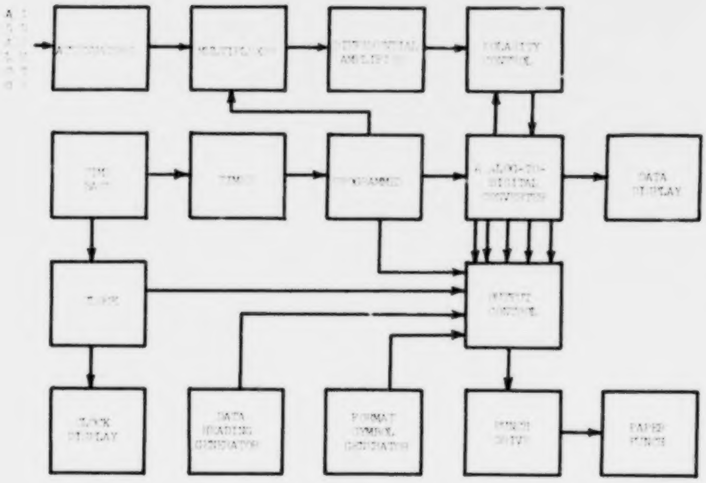

ATTENUATORS
MULTIPLEXER
DIFFERENTIAL AMPLIFIER
POLARITY CONTROL
TIME BASE
TIMER
PROGRAMMER
ANALOG-TO-DIGITAL CONVERTER
DATA DISPLAY
CLOCK
OUTPUT CONTROL
CLOCK DISPLAY
DATA HEADING GENERATOR
FORMAT SYMBOL GENERATOR
PUNCH DRIVE
PAPER PUNCH

FIG. 2. Recording system block diagram.

the input and working toward the output, it is believed that because of the multiple inputs, the explanation will be more understandable by starting at the output and working back to each of the four input sources.

Starting at the right side of the diagram is the 8-level paper punch which records the output information on 1-in. paper tape in a format appropriate for the computer to be utilized. The tape code to be punched is determined by the state of the 8 punch-magnet controls at the time that the punch command is received. The punch drive supplies the necessary power for energizing the code magnets and punching clutch. The output control, which is commanded by the programmer, selects the appropriate data source to be recorded by any given punching operation.

The four sources of signals selected by the output control are (1) the analog-to-digital converter that generates the data signal and sign, (2) the clock that generates time in hours and minutes, (3) data heading generator that generates a three-digit identification number which is recorded once during each data frame, and (4) the format symbol generator, to be described in the format section. The programmer is the heart of the recording system. It determines the sequence in which all data are recorded, controls the multiplexer that determines which input channel is to be recorded, and "tells" the analog-to-digital converter when to begin its conversion process.

The four signal sources are next discussed. The most important source is that which converts the incoming analog data to a digital form. Differential or single ended outputs from any of the sensors are applied to individual isolated attenuators. The multiplexer, operating under control of the programmer, selects one sensor output at a time and directs this signal to the differential amplifier (gain = 1,000). The output of the differential amplifier is applied to a low noise, double pole, double throw relay, which is used to invert the polarity of the signals when appropriate. The first step in the analog-to-digital conversion process, which also is under the control of the programmer, is to test for sign of the input signal. During the sign test, if the applied voltage is less than one resolution element positive (10 mv at the output of the differential amplifier), the polarity control is activated and the analog-to-digital conversion process is repeated. This means that if the value of the signal is actually zero, it will be recorded as a minus zero. The analog-to-digital converter generates a ramp voltage in proportion to the count of the cycles of an internal clock. When the ramp voltage, so generated, is one half a resolution element larger in magnitude than the applied voltage, the counter is stopped. The magnitude of the count is proportional, then, to the input voltage. Each of the three digits have their outputs indicated in a conventional binary coded decimal, four-bit code. The eight bits of the tens and units count are grouped together in one punch operation, while the hundreds count, sign, and over scale indication are grouped in another punch operation.

The clock signal is produced by a counting technique similar to that of the analog-to-digital converter. The time base, obtained from a tuning fork, is divided to provide one output pulse per minute. The one pulse per minute signal is divided by ten to produce a one pulse per 10-min signal; the one pulse per 10 min is divided by six to produce a one pulse per hour signal; and the hour signal is divided by 24 to produce a 24-hour clock. In this case, the minutes and the tens of minutes are grouped for one punching operation, while the hours and tens of hours are grouped for another punching operation.

The heading signal generators are three manually adjusted, ten-position switches that produce the appropriate BCD code for each position. The tens and units digits are grouped together for one punching operation and the hundreds digit is recorded in another punching operation. The three-digit heading code is used to record the date in form of day of the year as a convenient means of record identification.

The format symbol generator generates fixed signals which are explained in the tape format description. These symbols do not change, and are, therefore, permanently wired.

## RECORD TAPE FORMAT

The number of possible tape recording formats is almost infinite, the choice depending primarily on the desire of being able to monitor the tape (either visually or by play-back through a teletypewriter), or for tape economy where it is desired to operate the equipment for long periods of time unattended. Probably the easiest tape for an untrained operator to read is one in which each character occupies a single punch position. For numeric characters, binary coded decimal (BCD) symbols, up to four punches are used. If a code such as the ASCII is used (whose numerics are also BCD), the tapes may be inserted directly into a teletypewriter for immediate printout. It is apparent, since no more than half of the eight possible hole positions are being utilized, that this format has low tape economy. At the other extreme,a pure binary code may be used, utilizing all eight code levels in which any one of 256 message symbols are possible. This code is extremely difficult for an operator to read visually, requires extensive decoding before printout can be accomplished, but is the best format from standpoint of tape economy. For the recording system discussed here, a compromise between these two extremes is made. Basically, each eight level punch position was broken up into two four level BCD characters. This makes it possible for an operator to readily read the code, and while not as efficient as pure binary, each punch signal indicates any one of 100 conditions. This code may also be easily decoded for direct printout by a teletypewriter.

Figure 3 shows the format of the tape code. The format symbol generator generates a "begin frame" indication consisting of two entirely blank spaces. This format symbol allows the computer to "know" that a new data frame is beginning. Note the dummy punch, x, that appears in column B. These are used to allow the computer to differentiate between a zero value of a data entry and a "begin frame" indication. The over-volts punch is included and will be punched any time the magnitude of the particular variable exceeds the maximum selected scale value. This feature is necessary because the analog-to-digital converter

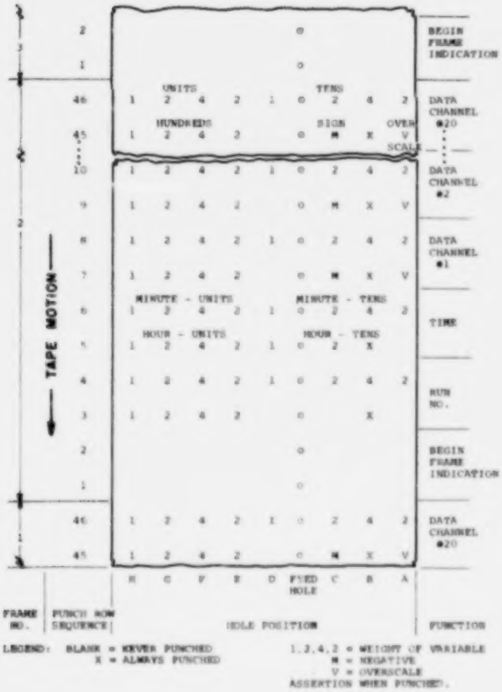

BEGIN FRAME INDICATION
UNITS
TENS
HUNDREDS
SIGN
OVER SCALE
DATA CHANNEL #20
DATA CHANNEL #2
DATA CHANNEL #1
MINUTE - UNITS
MINUTE - TENS
HOUR - UNITS
HOUR - TENS
TIME
RUN NO.
TAPE MOTION
H G F E D FEED HOLE C B A
FRAME NO.
PUNCH ROW SEQUENCE
HOLE POSITION
FUNCTION
LEGEND: BLANK = NEVER PUNCHED
X = ALWAYS PUNCHED
1,2,4,2 = WEIGHT OF VARIABLE
M = NEGATIVE
V = OVERSCALE
ASSERTION WHEN PUNCHED.

FIG. 3. Digital punched paper tape format.

will reset upon reaching full scale and an erroneous value will be recorded. The computer is programmed to reject all data points where the over-volts code appears.

## SENSOR SYSTEM

The sensors of the data acquisition system can be described in four basic groups. These are ship navigation, temperature, wind, and radiation. Description of the sensor systems is in terms of these groups. The systems are composed of commercial sensors with only minor modifications so that detailed descriptions are not included.

### SHIP NAVIGATION SENSORS

Interpretation of meteorological information measured aboard a ship requires knowledge of the ship speed, heading, and location so that the measured variables can be corrected for ship motion and so that the location of observations is known. Methods of obtaining a record of ship speed and heading or ship location must, necessarily, depend upon the navigation equipment available on the individual ship.

Ship location is a difficult parameter to record automatically because it is a derived rather than a measured value. For operation on the Great Lakes where stops at known ports are frequent, it is possible to record only ship heading and speed, allowing computer analysis to determine location. Accumulated errors are corrected each time the ship reaches a known location.

Ship speed is not measured directly on ships operated by the Great Lakes Research Division. Engine speed is measured by a tachometer generator and recorded either as a direct voltage input or is entered as a manual entry by the ship's captain. A relationship between engine speed and ship speed is known with reasonable accuracy but does not take current drift into account. Errors may, therefore, amount to the magnitude of the drift current.

Ship heading is obtained in the form of voltage proportional to the sine and cosine of heading relative to north. The measurements are obtained either from a sine resolver attached to a gyrocompass repeater or as a manual input to the recording system by the captain, depending upon the ship's equipment. Recording of the functions rather than heading in degrees allows for ease of computer reduction of the ship velocity into north and east components.

## TEMPERATURE SENSORS

The basic temperature measurements desired are air temperature, dew point temperature, and water temperature. In the present application, air temperature is measured at the mast head and on a bowsprit forward of the ship's bow. Dew point is measured only on the mast. Water temperature is measured at the intake to the ship's engine cooling system. The exact height of these measurements with reference to the water surface varies from ship to ship and also varies as the ship pitches in a rough sea.

Resistance elements were selected as the primary temperature sensors to provide the voltage output required for the recording system. Platinum resistance elements manufactured by Rosemount Engineering Company were mounted in a flat plate radiation shield as shown in Fig. 4. While it has been shown this type of exposure can result in significant error due to radiation under conditions of low sun angle and low ventilation, it is employed because forced aspiration is difficult to achieve in many shipboard installations. Ship motion provides ventilation in most cases thus reducing measurement errors to small values.

A Honeywell Dew Probe mounted in a weather shield of local manufacuture is used as the dew point sensor. This unit is also shown in Fig. 4. The Dew Probe employs a heated lithium chloride element of a type extensively tested by Hedlin and Trofimenkoff (1965). While these tests have shown that elements of this type do not give dew point measurements of high accuracy, errors of less than 0.5°C can be expected.

Resistance bridges and bridge chassis made by Rosemount Engineering Company are used with both the temperature and dew point sensors. The temperature elements and bridges are calibrated individually by the manufacturer as matched pairs to an accuracy of ± 0.01°F. A special bridge trimmed to the calibration determined for the dew point sensor is provided. In all cases, the bridge outputs are ±10 mv

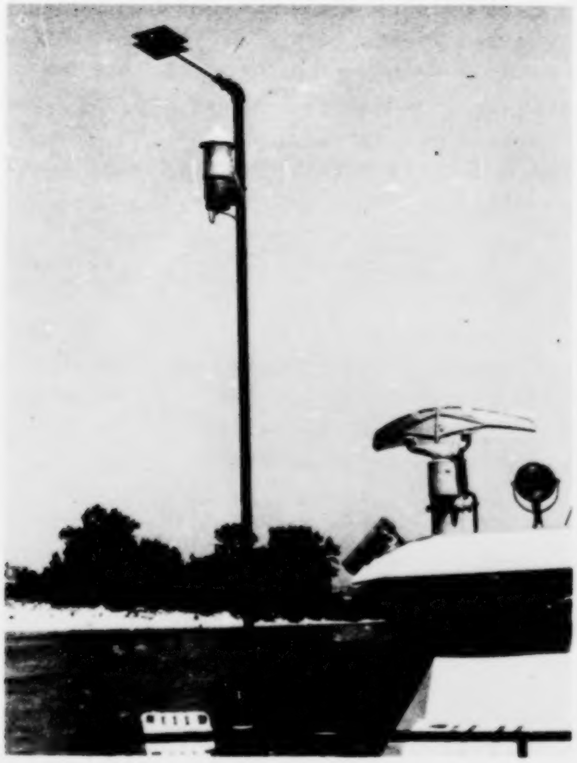


FIG. 4. Air temperature radiation shield and dew point sensor weather shield.

for a temperature range of -10 to 40°C with bridge balance at 15°C. The output voltage is considered a linear function of temperature within 0.1°C over the above range.

## WIND SENSOR SYSTEM

To be meaningful, wind measurements made aboard a moving ship must be corrected to compensate for the ship movements. The mean speed and heading of the ship are recorded, as described above, and applied as a correction to the apparent wind in computer determination of the true wind. The uneven, irregular roll of the ship induces an unevaluated error in wind measurements.

The wind speed and direction sensors are specially modified instruments manufactured by the Electric Speed Indicator Company. The speed sensor is a three cup anemometer driving a D. C. tachometer generator. Wind direction relative to the ship heading is sensed by a vane coupled directly to a sinusoidal potentiometer having both sine and cosine functions. The output voltage from the speed sensor is applied directly to the sine-cosine resolver. Two voltages are thus obtained, one proportional to the apparent wind speed multiplied by the sine of an angle with reference to the ship's heading, and a second proportional to the wind speed multiplied by the cosine of the same angle. These voltages are a measure of the relative wind speed normal to the bow and beam of the ship and are recorded directly. Anemometers are exposed atop the highest point on the ship's mast and, in case of one ship, at the end of a 20-ft bowsprit. The ability of such an anemometer exposure to measure wind speed profile over the lake is yet to be evaluated.

## RADIATION MEASUREMENT SYSTEM

Four components of radiation are measured to obtain the radiation balance at the air-water interface. They are (1) the incoming solar radiation both direct and diffuse, (2) reflected solar radiation, (3) net exchange radiation and (4) long wave emission from the water surface.

Incoming solar radiation is measured with a standard 50-junction, temperature compensated, Eppley Pyrheliometer. This instrument is the standard employed by the U.S. Weather Bureau for measurement of solar radiation and is described by Kimball and Hobbs (1923) and by Karoli, Angstrom, and Drummond (1960). Use aboard ship requires mounting on a gimbal because measurement of the radiation incident upon a horizontal surface is desired. A simple ring gimbal, as shown in Fig. 5, has performed satisfactorily under most conditions encountered.

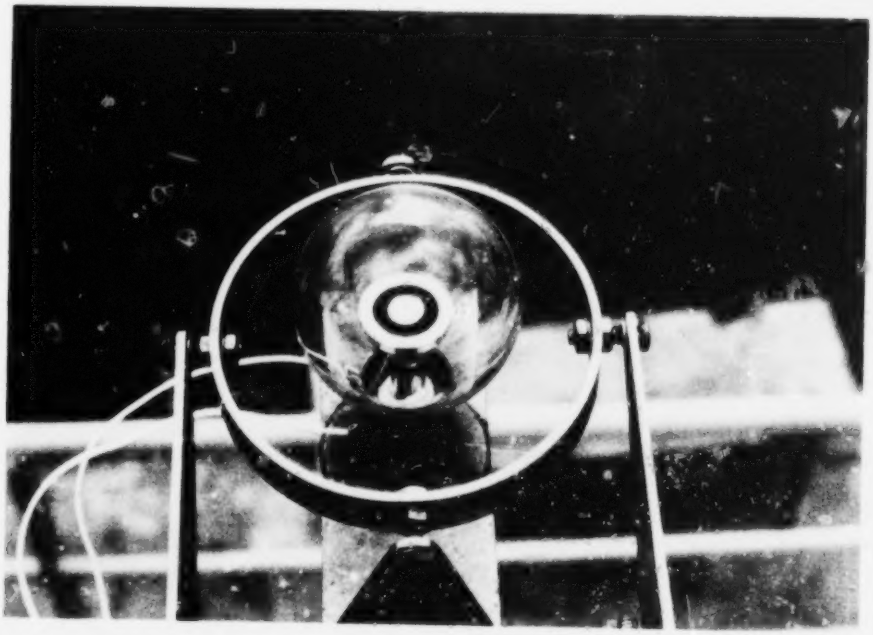


FIG. 5. Eppley Pyrheliometer showing gimbal mounting.

Measurement of net radiation exchange and reflected solar radiation require that the sensors have an unobstructed view of the water surface. This is accomplished by mounting the sensors on a gimbal suspended from a bowsprit as shown in Fig. 6. An Eppley Pyrheliometer inverted and shielded from radiation arriving from the upper hemisphere is used to measure the reflected solar component. This instrument has been commonly used for such albedo measurements, but slight errors may result as shown by Fruquay and Buettner (1957).

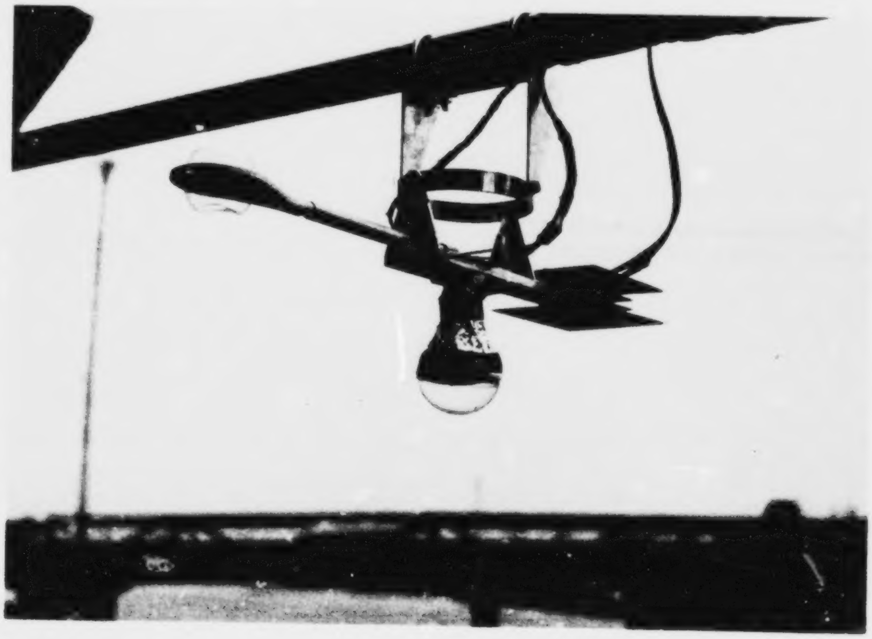


FIG. 6. Funk net exchange radiometer, inverted Eppley Pyrheliometer, and air temperature radiation shield mounted on a gimbal.

Net radiation exchange is measured with a polyethylene shielded heat flow transducer manufactured by Middleton and Company, Melbourne, Australia. This instrument designed by Funk (1959), working with the Commonwealth Scientific Industrial Research Organization, is convenient for gimbal mounting due to its small size. The polyethylene spheres are kept inflated by either compressed nitrogen or dried air. This instrument is also shown in Fig. 6. A thorough evaluation of instruments of this type appears to be lacking, although they are in general use in radiation balance studies (see Gates, 1962).

Radiation emitted by the water surface is sensed by an infrared thermometer, Barnes Model IT-2, which measures the radiation received from a 5-degree field of view. The received radiation is compared to a reference blackbody controlled at 50°C and the differential displayed as radiation temperature of the object in the field of view, assuming blackbody emissivity. Filters exclude radiation except in the 8' to 13-μ region of the spectrum so that reflected solar radiation is not observed. This instrument has been evaluated by Ichiye and Plutchak (1965) and employed in many cases to sense remotely water surface temperature.

It is known that emission and absorption by gases, particularly water vapor, between the sensor and water surface will cause errors in the measured water temperature. These errors will, however, be small when the instrument is exposed near the water surface as on a ship. Frequent and careful calibration of the instrument using a stirred water bath is necessary.

## REFERENCES

BELLAIRE, FRANK R. 1963. Relation of winds, water levels and water temperatures to currents in lower Lake Michigan. Proc. 6th Conf. on Great Lakes Research; Univ. of Michigan, Great Lakes Res. Div. Pub. 10: 219-230.

BRUCE, J. P., and G. K. RODGERS. 1962. Water balance of the Great Lakes system, p. 41-69. In Great Lakes Basin, American Association for the Advancement of Science, Pub. 71. Washington, D.C.

FUNK, J. P. 1959. Improved polyethylene-shielded net radiometer. J. Sci. Inst., 36: 267-270.

FRUQUAY, D., and K. BUETTNER. 1957. Laboratory investigation of some characteristics of the Eppley Pyrheliometer. Trans. Amer. Geophys. Union, 38(1): 38-43.

GATES, DAVID M. 1962. Energy exchange in the biosphere. Harper and Row, New York, 74-93.

HEDLIN, C. P., and F. N. TROFIMENKOFF. 1965. An investigation of the accuracy and response rate of a lithium chloride heated electrical hygrometer, p. 627-634. In Humidity and Moisture, Measurement and Control in Science and Industry, Reinhold, N. Y.

ICHIYE, TAKASHI, and N. B. PLUTCHAK. 1965. Calibration and field tests of infrared temperature thermometers. Lamont Geological Observatory, Columbia University, New York, AD470136.

JACOBS, STANLEY J. 1965. Wave hindcasts vs. recorded waves. University of Michigan, Office of Research Administration Rept. 06768-1-F, Ann Arbor, Michigan.

KAROLI, A. R., A. K. ANGSTROM, and A. J. DRUMMOND. 1960. Dependence on atmospheric pressure of the response characteristics of thermopile radiant energy detectors. J. Opt. Soc. Amer., 50: 758-763.

KIMBALL, H. H., and H. E. HOBBS. 1923. A new form of thermo-electric recording pyrheliometer. Monthly Wea. Rev., 51: 239-242.

PLATZMAN, GEORGE W. 1965. The daily variation of wind set-up on Lake Erie. Proc. 8th Conf. on Great Lakes Res.; Univ. of Michigan, Great Lakes Res. Div. Pub. 13: 273-277.

# A SUPPLEMENT TO "THE CLIMATOLOGY OF LAKE MICHIGAN"

John C. Ayers and Alan E. Strong

"The Climatology of Lake Michigan" (Ayers 1965, hereinafter called the original report) developed from the paradox that raw-water temperatures at the intakes of the Chicago Water Department have shown a cooling trend over the period of record, despite equally valid evidence that air temperatures in the Great Lakes basin have shown a warming trend since the beginning of records.

From a mixture of reasoning from first principles and of trial and error, it gradually developed that the essential features of the Chicago water temperature record could be imitated by the algebraic combination of 5-year running-average curves for annual numbers of storm passages, reciprocal numbers of cloudy days, and air temperature at small towns on the upwind side of the lake.

The original report pointed out the possibility that the observed diminishing numbers of storm passages might be allowing the formation of shallower warmer epilimnions with consequent density-gradient insulation of the body of the lake against the mixing in of heat. Warmer, even if shallower, epilimnions could account for the increasing amounts of western Michigan snowfall being found by Dr. Val L. Eichenlaub of Western Michigan University (personal communication). Further, if the thickness and heat content of epilimnions over the years could be determined it would provide an additional check on the possibility that density-gradient insulation was resulting from decreased numbers of storms.

Sources of older data from the lake were explored. The few giving reasonably wide areal coverage and the needed critical temperature data were the data of Van Oosten (1960) for the summers of 1930-32, of Church (1942), (1945) for the years 1941-42, and our own for 1962-65.

Church's data were primarily from the Muskegon-to-Milwaukee car-ferry crossing, and to maintain comparability, data from Van Oosten and ourselves were restricted to the same region. The data used are from the latitude-longitude rectangle bounded by 43°00'N, 43°30'N, 86°30'W, and 87°30'W.

From these studies we extracted data for monthly surface temperature, monthly values of the thermoclinal temperature gradient where it exceeded 1°C per 10 m (barely recognizable) and depth in meters to the middle of the thermoclinal gradient. These data were combined by three-month periods into summer (June through August) and fall (September through November) seasons.

Van Oosten's data were taken by reversing thermometer and may or may not have properly defined the thermocline. Church's data were by bathythermograph and can be considered comparable to our own later bathythermograph data in defining the location and temperature in the thermocline.

The numbers of data available are shown in Table 1.

TABLE 1. Numbers of data available.

| Month | Surface temperature | Midthermoclinal temperatures and depths |
|---|---|---|
| Van Oosten 1930-32 | | |
| June | 3 | 0 |
| July | 7 | 7 |
| August | 3 | 0 |
| September | 2 | 2 |
| Church 1941-42 | | |
| June | 3 | 3 |
| July | 4 | 4 |
| August | 5 | 5 |
| September | 3 | 3 |
| October | 0 | 0 |
| November | 2 | 2 |
| Great Lakes 1962-65 | | |
| June | 62 | 54 |
| July | 33 | 31 |
| August | 60 | 60 |
| September | 48 | 48 |
| October | 50 | 50 |
| November | 43 | 42 |

Van Oosten's nine midthermoclinal values in the midlake rectangular study area have been checked for representativeness against the 42 open lake stations that comprise the total of his data. The nine stations give exactly the same mean midthermoclinal temperature as the 42, and their average depth to midthermocline differs by only 3 m from the mean of 42. Since the nine stations in the study rectangle adequately represent a much larger body of data they have been deemed acceptable to indicate conditions in 1930-32.

The distribution of Church's fall data (in September and November) have been judged sufficient to allow the taking of means for that season of 1941-42.

Our own 31 values for midthermoclinal depth in July and the 50 for the same parameter in October indicate less depth to midthermocline than in the preceding or following months. We have been unable to find any error in the values and they are used.

From the three sets of data we have computed the mean surface temperature, the mean midthermoclinal temperature and the mean depth to midthermocline. Mean surface and mean midthermocline temperatures have been averaged to obtain mean epilimnetic temperatures which have been multiplied by mean depth to midthermocline to estimate heat content in a square-meter column of epilimnion. The results are shown in Table 2.

It is evident from Table 2 that the epilimnion was warmer and shallower in both summer and fall in 1962-65 than in 1941-42. It is also indicated in Table 2 that the epilimnion of 1962-65 contained less heat to be lost to the atmosphere and mixed into the body of the lake during fall storms than was the case in 1941-42. Comparisons between 1941-42 and 1962-65 would confirm the two basic hypotheses of the original report: (1) that reduced number of storms was an important factor in the thermal history of the lake, and (2) that density-gradient insulation of the main body of the lake was perhaps the mechanism by which thermal energy of the warming air was denied entry into the lake.

However, the fact that we cannot demonstrate unrepresentativeness of Van Oosten's data forces us to consider the indicated condition of the epilimnion in the summer of 1930-32 as real. If this be the case, then there have been periods of warmer shallower epilimnions in the past. If, again, this be the case, and if the hypotheses of the original report contain all the important climatological factors, the period of reduced heat input in 1962-65 and the probable reduced input in 1930-32 and the increased input in 1941-42 should correlate to two cooling periods and one warming period in the record of water temperature. These correlations have been sought but not found. Figure 1 shows the water temperature record at Chicago and Milwaukee with the 1930-32, 1941-42 and 1962-65 periods indicated. In this figure it appears, indeed, that the water temperature may be responding to mere level of the epilimnion temperature, and that the basic downward trend of water temperature may be in response to (or include significant effect of) some factor not yet recognized.

TABLE 2. Surface temperatures; midthermocline temperatures, and depths. All weighted averages.

| Month | 1930-32 (data of VanOosten) | | | 1941-42 (data of Church) | | | 1962-65 (data of GLRD) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Surface | Midthermocline | | Surface | Midthermocline | | Surface | Midthermocline | |
| | °C | °C | meters | °C | °C | meters | °C | °C | meters |
| June | 12.4 | 10.4 | 13.0 | 10.9 | 8.6 | 15.9 | 13.0 | 8.4 | 19.3 |
| July | 18.5 | 13.8 | 14.5 | 18.9 | 11.9 | 22.7 | 19.5 | 12.1 | 11.8 |
| August | 20.4 | 12.9 | 19.1 | 21.2 | 13.2 | 25.8 | 19.7 | 12.3 | 24.7 |
| Summer means | 17.1 | 12.4 | 15.5 | 17.0 | 11.2 | 21.5 | 17.4 | 10.9 | 18.6 |
| | 14.8° | | 15.5 m | 14.1° | | 21.5 m | 14.2° | | 18.6 m |
| Summer heat content gm-cal/$m^2$ column | | $2.3\times10^8$ | | | $3.0\times10^8$ | | | $2.6\times10^8$ | |
| September | | | | 20.0 | 10.8 | 27.9 | 15.6 | 10.0 | 33.3 |
| October | | | | | | | 15.2 | 9.7 | 32.5 |
| November | | | | 7.1 | 5.8 | 63.5 | 10.6 | 7.6 | 42.2 |
| Fall means | | | | 13.6 | 8.3 | 45.7 | 13.8 | 9.1 | 36.0 |
| | | | | 11.0° | | 45.7 m | 11.5° | | 36.0 m |
| Fall heat content gm-cal/$m^2$ column | | | | | $5.0\times10^8$ | | | $4.1\times10^8$ | |
| Summer-to-fall heat content gain | | | | | $2.0\times10^8$ cal | | | $1.5\times10^8$ cal | |

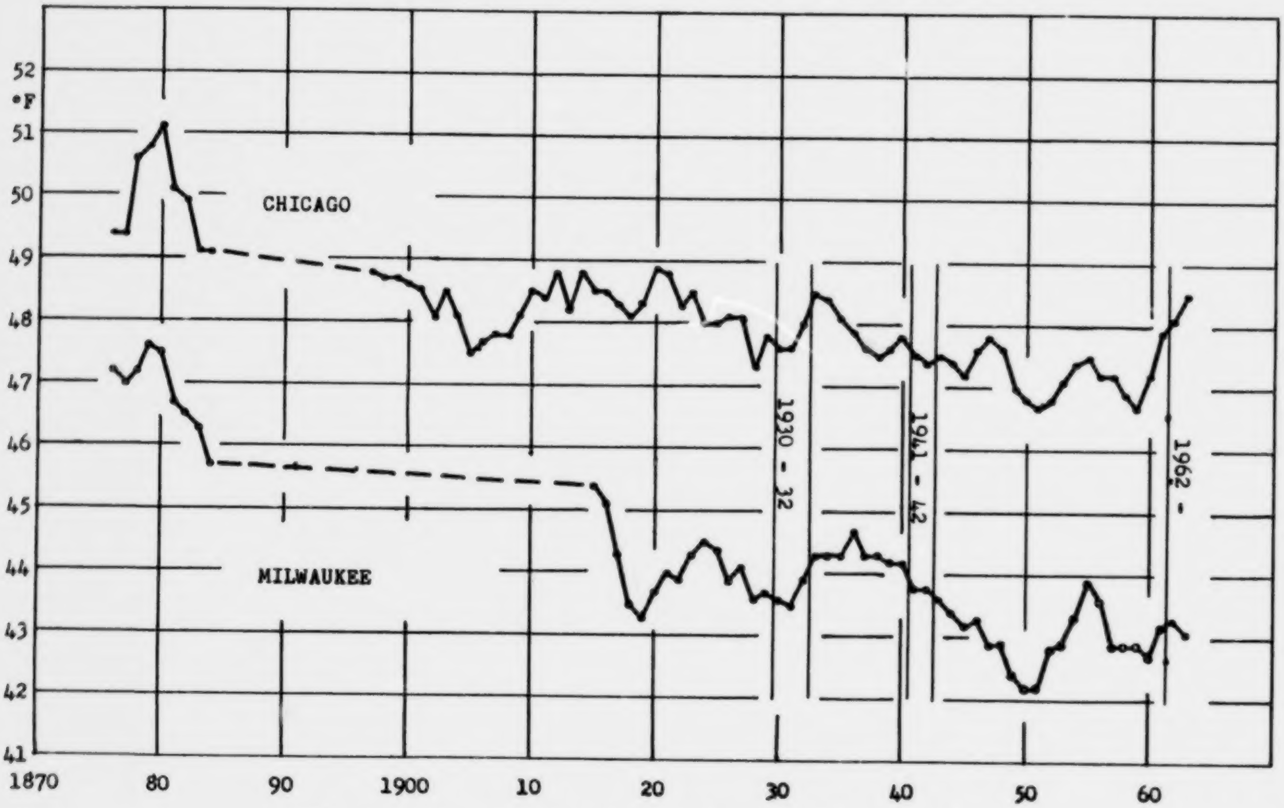


FIG. 1. Annual water temperatures, Chicago and Milwaukee, 5-year moving means.

As a means of revealing the factors controlling epilimnion development, a two-year study was made. Since the change from isothermal water to thermocline-separated epilimnion and hypolimnion waters transpires during the spring, the study was concentrated around the four spring months (March through June) of 1965 and 1966. Surface water temperature data and total southern-basin heat content data were available for these two successive springs. Solar radiation and both over-water and over-land winds and air temperatures were also examined.

Bathythermograph stations have been maintained along three fairly equally spaced east-west lines in the southern basin of Lake Michigan. The 21 stations in this network were sampled near the end of each of the spring months during the two years. From these temperature data monthly heat content of the southern basin was computed. Successive subtractions of these monthly values give monthly heat inputs.

Surface temperature charts for the two springs were analyzed for average surface temperature over the southern basin (south of 43°N). These data provided an indication of the epilimnion heat content.

Solar radiation data were available from Madison, Wisconsin, and South Haven and Sodus, Mich.; they were, unfortunately, incomplete. However, the indication from the sparse data was of quite similar total solar radiation over the two spring periods. Further confirmation of this agreement came from an analysis of "percent possible sunshine" data from General Mitchell Field, Milwaukee, Wis., during the two springs.

Total heat content in the southern basin was much higher at the start of the 1966 spring season than in 1965. Figure 2 shows nearly as much stored heat at the end of March 1966 as had been the case at the end of April in 1965, suggesting that 1966 had been a milder winter. However, by the end of June, in both years, nearly equal amounts of heat were stored in the southern basin. Much more concentrated heating is inferred during May and June of 1965 than in the following year. In summary, the water during the spring of 1965 received a much larger heat input than during the 1966 spring. We point out again that over these two periods insulation was nearly equal.

Surface temperatures at the end of June showed a much higher average over the southern basin in 1966 than in 1965—21.9°C versus 14.5°C--as shown in Fig. 3. While surface data were not available in March of 1965, the monthly trends indicated a 1965-1966 difference in this parameter which increased through the spring.

Logic dictates that solar radiation, while important in heating the epilimnetic water, is not the sole--and may not be the primary--mechanism for quantitative heat transfer into a warming lake. The density-gradient insulation already suggested needs to be seriously considered.

Transfer of surface-water heat to lower water levels requires mixing from wind stress. As shown by Strong and Bellaire (1965) the spring months may be classified into stable and unstable periods. Unstable periods, when the air temperature is cooler than the water, become progressively rare during the last half of the spring. During these periods the winds at land stations will, as a rule, be less than those over the lake (Hunt 1958). Heat already in the lake will be mixed more uniformly and some lost back to the atmosphere.

Stable periods, with their characteristic inversions over the lake, reach a maximum frequency during late spring and early summer. The protective inversion reduces wind velocities over the lake. These more gentle winds both allow the establishment of the thermocline and mix heat from the air directly over the surface into the epilimnion. The strength of the resulting density-gradient insulation plays a vital role in the amount of heat permitted into the lake for the remainder of the spring and summer.

The hemispheric weather circulation becomes critical in mixing of heat in the Great Lakes to lower water depths. A hemispheric circulation which holds the storm track (low pressure regions) to the south of the Great Lakes during the spring produces fewer days of warm stable weather. The thermocline develops less rapidly and is more diffuse. On the other hand, a

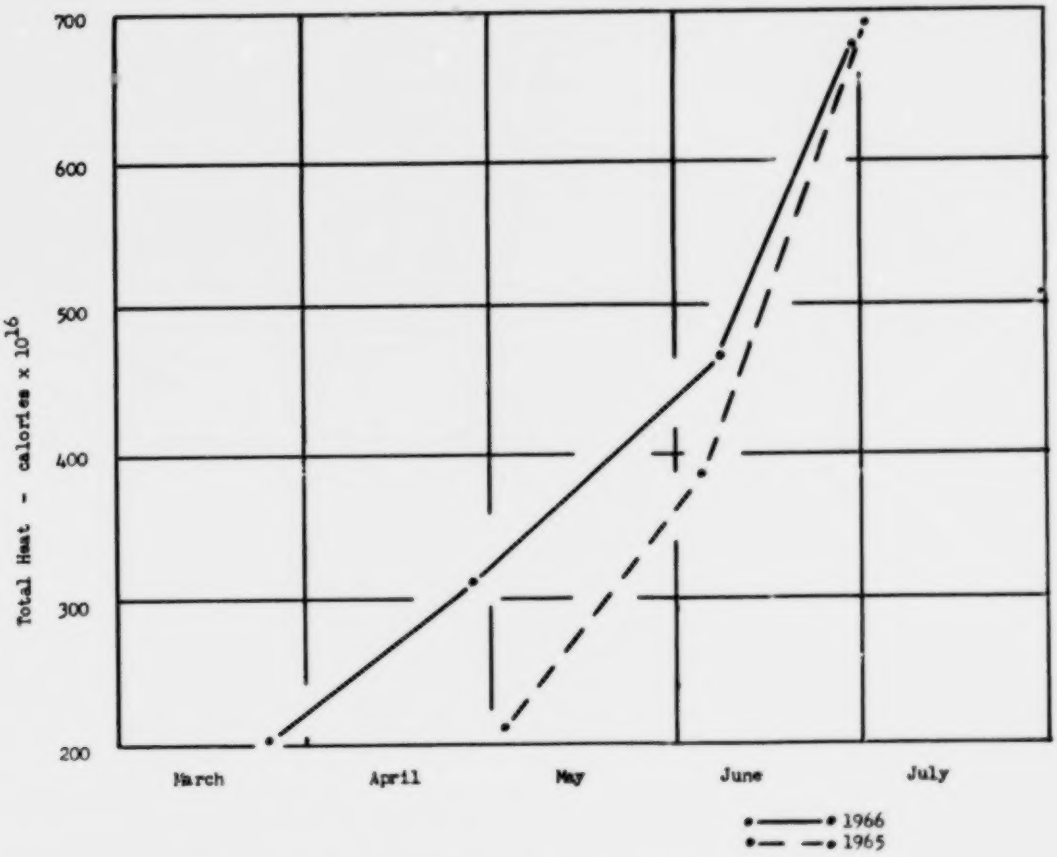


FIG. 2. Total heat content of southern basin.

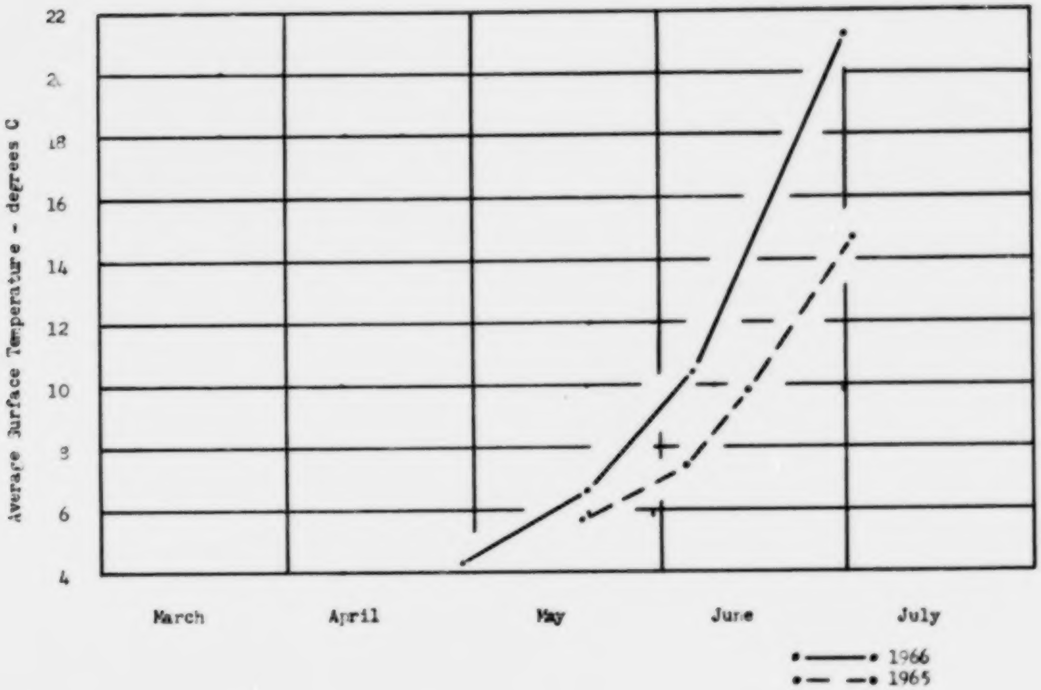


FIG. 3. Average surface temperature of southern basin.

concentration of low pressure passages to the north of the Great Lakes during the spring would, by stimulating warm air flows, provide a higher frequency of stable days and the subsequent earlier and more intense thermocline. Such a condition requires higher-than-normal air temperatures. The wind stress that is able to penetrate down through the inversion over the lake mixes the available heat into the developing epilimnion. We believe it necessary to consider some temperature-stress (air temperature-wind stress) parameter as a critical mechanism.

The 1966 spring was one whose temperature-stress was high. Meteorological records from ships on the lake and stations surrounding it indicate that the months of May and June in 1966 provided fewer windy days when the air temperatures were below normal than was true in 1965. June 1966 air temperatures were 2.1°C (Milwaukee) above normal, providing a nearly continuous stable period over the water. Transfer of heat to the hypolimnion was virtually cut off by mid May. By the end of June the epilimnion was much warmer and the hypolimnion somewhat cooler than at the same time in 1965. It appears that in addition to the solar radiation contribution to a heat budget the consequences of a temperature-stress parameter need to be included. Once a thermocline develops it may serve as a protective barrier against additional heat input to a lake.

## REFERENCES

AYERS, J. C. 1965. The climatology of Lake Michigan. Univ. Michigan, Great Lakes Research Div. Pub. No. 12, 73 p.

CHURCH, P. E. 1942. The annual temperature cycle of Lake Michigan. I. Cooling from late autumn to the terminal point, 1941-42. Misc. Reports No. 4, Inst. of Meteorology, Univ. of Chicago, Chicago, Ill.

__________. 1945. The annual temperature cycle of Lake Michigan. II. Spring warming and summer stationary periods, 1942. Misc. Reports No. 18, Dept. of Meteorology, Univ. of Chicago, Chicago, Ill.

HUNT, I. A. 1958. Winds, wind set-ups, and seiches on Lake Erie. A paper presented to the 2nd National Conference on Applied Meteorology (mimeographed).

STRONG, A. E. and F. R. BELLAIRE. 1965. The effect of air stability on wind and waves. Proc. 8th Conf. Great Lakes Res., Univ. Michigan, Great Lakes Research Div. Pub. 13: 283-289.

VAN OOSTEN, J. 1960. Temperatures of Lake Michigan, 1930-32. U. S. Dept. Interior, Fish and Wildlife Service, Special Scientific Report--Fisheries No. 322. 34 p.

# LAKE MICHIGAN METEOROLOGICAL DATA, 1963-66

Frank R. Bellaire, Floyd C. Elder and Alan E. Strong

Lake Michigan engages in modification of weather and air masses that cross it. The time rates of these changes and the geographic positions of rapid changes cannot accurately be known from data of weather stations on land. Similarly, several of the aspects of air-water interaction can be best measured or understood when there are suitable data from over the lake to supplement those of upwind and downwind land stations.

For many studies large quantities of data are required to ensure representative knowledge under different weather situations. For several types of studies involving short-period or local-area changes the data should be obtained at short time intervals. For these reasons, and for economy in personnel, automated recording of data is necessary. Automated data recording stations for the R/V INLAND SEAS and R/V MYSIS have been developed and used for two and one years respectively. The data from these recorders are supplemented by visual observations each hour that the ship is on the lake.

This paper presents the over-lake meteorological data for synoptic hours and for times of biological station-stops for the years 1963 through 1966. For evident reasons of bulk, the minute-by-minute data from the recording stations and the every-hour visual observations cannot be presented here. They are available at the Great Lakes Research Division.

We are grateful for the assistance in computer programming given by Fred V. Brock, Paul R. Harrison, Kenneth L. Davidson, and Wayne P. Alley. Instrumentation development and maintenance was very capably handled by Hung K. Soo. Franklin E. Dunster and Ronald Rossmann assisted the authors in tending the shipboard stations and in taking the visual hourly observations.

## EXPLANATION OF DATA SHEETS

Over-lake weather observations on R/V INLAND SEAS were begun in 1963 and on R/V MYSIS in 1964. A multipoint strip-chart recorder was used on each ship during the first year; automatic digital data recorders were installed on INLAND SEAS in 1964 and on MYSIS in 1965.

Our standard operating procedure requires the digital recorders to be turned on at pierhead when departing harbor and to be turned off at pierhead when entering harbor. It also requires the recorders to be turned off at each stop while on the lake, and to be turned on as each stop is departed. Visual observations are taken at each hour whenever the ship is underway outside pierheads. Data in the columns for Weather, Pressure, Clouds, Waves, and Swell are from the hourly visual observations; data for position are hand-determined from the ship's course on a chart of 0.1° squares. All other data are from the digital recorders and are available at one-minute intervals. All the observations reported here are from Lake Michigan.

The data here reported are in Great Lakes Weather Observation Format according to Reference Manual "International Marine Surface Data 128" with the exception of the hour and wave heights. The time (hour) is reported in Eastern Standard Time and wave heights in feet.

Column headings and abbreviations used are:

| | |
|---|---|
| Times | |
| DY | Day |
| HR | Hour (EST) |
| Locations | |
| LATD | Latitude in degrees and tenth degrees |
| LONG | Longitude in degrees and tenth degrees |
| Winds | |
| DD | Wind direction in tens of degrees |
| FF | Wind speed in knots |
| Weather | |
| VV | Visibility according to Standard Marine Code |
| WW | Present weather by Standard Marine Code |
| W | Past weather according to Standard Marine Code |
| Pressr | |
| PPPPPP | Barometric pressure in millibars |
| | Not installed, or not functioning |
| OKT Cloud | Octal Cloud Cover |
| N | Total cloud amount, by eighths of sky covered |
| A | Low cloud amount, eighths of sky covered |
| L | Coded low-cloud type |
| M | Coded middle-cloud type |
| H | Coded high-cloud type |
| Temepratures,°C | |
| AIRM | Masthead air temperature |
| AIRB | Bowsprit air temperature |
| WATI | Water temperature at ship's intake |
| WATS | Surface water temperature, by bowsprit trailing sensor |
| TDPT | Dew-point temperature |
| | Not installed, or not functioning |

| | |
|---|---|
| Waves | |
| DD | Direction waves come from, in tens of degrees |
| HH | Wave height in feet |
| Swell | |
| DD | Direction swells come from, in tens of degrees |
| HH | Swell height in feet |
| Radiation | |
| SOLR | Solar radiation by Eppley pyrheliometer, in langleys/min. |
| NETR | Net radiation, langleys/ min. |
| . | Not installed, or not functioning |
| V | Vessel |
| 1 | R/V INLAND SEAS |
| 2 | R/V MYSIS |

The heights of the various sensors, in feet above the water surface, on the two ships are as follows:

| | INLAND SEAS | MYSIS |
|---|---|---|
| Wind | 48. | 37. |
| Mast temperature (AIRM) | 38.5 | 36. |
| Bow temperature (AIRB) | 15.5 | 16.5 |
| Dew-point temperature (TDPT) | 38.5 | 15.5 |
| Water intake temperature (WATI) | -10. | -4. |
| Water surface temperature (WATS) | 0 | 0 |
| Solar radiation (SOLR) | 25.5 | 14. |
| Net radiation (NETR) | 15.5 | 10. |

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TIMES LOCATIONS WINDS WEATHER PRESSR OKT CLOUD TEMPERATURES (DEGREES C) WAVES SWELL RADIATION V
DY HR LATD LONG DD FF VV WW W PPPPPP N A L M H AIRM AIRB WATI WATS TDPT DD HH DD HH SOLR NETR V

                                          APRIL 1963

22 13 42.6 86.3 09 06 98 01 2      . 6 6 0 7 X 05.5   .  02.9   .  00.6 01 01          .    . 1
24 13 42.1 86.8 31 05 97 05 0      . 0 0 0 0 0 04.6   .  02.0   .  02.2 00 00 28 00    .    . 1
25 07 42.0 86.5 16 08 97 05 2      . 6 6 0 1 X 05.4   .  07.0   .  01.5 14 00          .    . 1
25 13 41.9 87.0 00 00 96 05 2      . 7 7 0 7 X 05.7   .  02.2   .  03.8 00 00          .    . 1
26 07 41.6 87.0 09 03 96 05 0      . 3 3 5 0 0 08.3   .  08.0   .  06.5 00 00          .    . 1
26 13 41.7 87.4 09 10 96 05 0      . 0 0 0 0 0 12.1   .  11.0   .  06.8 00 00          .    . 1
27 13 41.8 87.2 06 04 96 05 1      . 0 0 0 0 0 06.9   .  03.4   .  04.5 00 00          .    . 1
28 13 41.8 87.4 12 11 98 02 2      . 6 6 0 5 X 11.0   .  09.0   .  06.6 09 01          .    . 1
29 13 41.8 87.5 21 08 98 01 6      . 6 6 2 X X 17.4   .  11.2   .  13.4 14 01          .    . 1

                                           MAY 1963

01 13 42.4 87.0 25 03 98 03 0      . 3 3 0 0 1 02.6   .  02.2   .  -0.1 00 00 36 02    .    . 1
20 13 43.0 86.3 22 12 98 02 0      . 0 0 0 0 0 08.0   .  09.0   .  04.3 22 00          .    . 1
20 19 43.0 87.7 19 18 98 02 0      . 0 0 0 0 0 06.8   .  04.1   .  01.9 18 02          .    . 1
21 07 43.0 87.8 25 06 98 02 0      . 1 1 0 3 0 08.9   .  08.2   .  05.4 49 00          .    . 1
21 13 42.4 87.7 27 20 98 03 1      . 5 5 2 0 0 12.1   .  08.5   .  01.5 27 01          .    . 1
22 07 41.8 87.5 32 15 98 02 2      . 8 8 5 X X 07.4   .  10.8   .  00.4 32 00          .    . 1
22 08 41.8 87.4 32 18 98 01 2      . 7 7 5 X X 07.3   .  09.5   .  01.1 32 01          .    . 1
22 10 42.0 87.2 32 05 98 01 1      . 2 2 5 5 0 04.6   .  04.0   .  01.8 32 01          .    . 1
22 13 42.3 87.0 00 00 98 03 1      . 8 8 5 X X 05.0   .  03.5   .  01.5 00 00 32 01    .    . 1
22 16 42.4 86.9 32 08 98 02 2      . 8 8 5 X X 04.5   .  03.5   .  01.9 00 00 36 02    .    . 1
22 19 42.8 86.6 30 05 98 01 2      . 5 5 5 0 0 04.2   .  04.5   .  02.2 00 00 36 01    .    . 1

                                          JUNE 1963

03 13 42.4 86.9 18 04 90 47 4      . 9 9 X X X 07.5   .  04.5   .  07.5 00 00          .    . 1
04 07 41.8 87.5 32 06 96 05 4      . 0 0 0 0 0 17.5   .  17.0   .  15.5 00 00          .    . 1
04 13 41.8 87.5 04 12 96 05 4      . 4 4 0 0 1 17.5   .  17.5   .  16.0 04 00          .    . 1
06 13 41.8 87.5 22 03 96 05 4      . 3 3 2 0 0 21.5   .  18.5   .  19.0 00 00 04 00    .    . 1
08 07 42.0 87.2 15 06 97 05 4      . 8 8 X X 7 17.8   .  16.7   .  16.0 00 00 20 00    .    . 1
08 10 42.3 87.0 17 12 90 47 4      . 9 9 X X X 11.5   .  05.0   .  11.5 00 00 18 00    .    . 1
08 13 42.6 86.9 16 05 93 44 4      . 6 6 3 7 X 09.4   .  04.8   .  08.8 00 00 18 01    .    . 1
18 13 43.3 87.1          98 02 0      . 1 1 0 1 0    .      .     .     .     .    . 07 00          .    . 1
19 13 42.4 86.9 16 02 97 05   1012.0 7 7 0 7 7 13.4   .  06.9   .  10.3 16 02          .    . 1
24 07 43.0 86.3 00 00 97 02 0 1031.0 0 0 0 0 0 13.0   .  11.0   .  09.4 00 00          .    . 1
24 13 43.0 87.3 16 06 97 03 1 1029.0 5 5 0 0 1 14.8   .  12.7   .  11.9 24 00          .    . 1
25 07 43.3 87.7       98 01 2 1026.0 4 4 0 0 1 14.6   .  13.7   .  12.6 00 00          .    . 1
25 13 43.3 87.4 12 07 98 01 0 1024.0 2 2 0 0 1 18.3   .  15.7   .  11.6 12 00          .    . 1
25 19 42.9 86.6 00 00 97 01 0 1020.0 1 1 0 0 1 21.3   .  14.7   .  09.9 00 00          .    . 1
26 13 43.0 86.2 16 06 97 00 0 1018.0 0 0 0 0 0 18.8   .    .    .  15.0 16 00          .    . 1
27 07 43.0 86.3 16 04 96 00 0 1015.0 1 1 0 4 0 16.9   .  13.6   .  14.7 00 00          .    . 1
27 13 43.0 87.3 16 08 96 03 0 1014.0 2 2 0 4 0 17.2   .  15.1   .  14.7 16 00          .    . 1
28 07 43.0 87.7 02 10 97 02 2 1013.0 8 8 7 X X 16.3   .  15.6   .  14.0 01 01          .    . 1
28 13 43.1 87.4 35 08 97 02 2 1013.0 8 8 0 7 X 17.3   .  14.3   .  13.8 02 01          .    . 1
28 19 43.0 86.4          02 2 1011.0 8 8 0 7 X 18.8   .    .    .  17.2                .    . 1
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TIMES LOCATIONS WINDS WEATHER PRESSR CKT CLOUD TEMPERATURES (DEGREES C) WAVES SWELL RADIATION V
DY HR LATD LONG DD FF VV WW W PPPPPP N A L M H AIRM AIRB WATI WATS TOPT DD HH DD HH SOLR NETR V

                                 JULY 1963

02 13 43.0 86.5 32 12 98 02 0      . 0 0 0 0 0 16.8    . 14.8    . 14.3 34 01          .    .  1
03 07 43.0 86.2 32 10 98 02 0      . 1 1 0 0 1 13.0    . 11.8    . 09.3 32 01          .    .  1
08 07 43.0 86.2 05 06 98 02 0 1016.8 0 0 0 0 0 13.6    . 06.6    . 09.8 34 00          .    .  1
08 13 43.6 86.8 36 12 98 03 0 1017.0 1 1 0 0 1 13.0    . 12.8    . 11.3 36 01          .    .  1
08 19 43.8 86.6 36 12 98 03 0 1016.5 6 6 0 0 1 14.0    . 11.9    . 09.0 36 00          .    .  1
09 13 44.3 87.2 34 03 98 03 0 1018.0 2 2 0 1 0 14.5    . 14.5    . 09.4 00 00 32 00    .    .  1
09 19 44.3 86.7 04 03 98 01 0 1015.9 0 0 0 0 0 14.4    . 12.5    . 10.8 00 00 32 00    .    .  1
10 13 44.2 86.7 14 02 98 02 0 1016.4 0 0 0 0 0 14.6    . 11.5    . 12.0 00 00 36 00    .    .  1
10 19 44.2 86.3 35 04 98 02 0      . 0 0 0 0 0 14.8    . 14.0    . 12.2 00 00 27 00    .    .  1
11 13 44.6 86.9 17 11 97 05 0 1019.1 1 1 0 0 0 14.6    . 12.5    . 11.0 18 00          .    .  1
12 07 44.6 86.3 16 12 97 05 2 1021.2 7 7 0 8 X 15.8    . 13.1    . 11.7 18 00          .    .  1
12 13 45.2 85.7 23 07 97 05 1 1020.0 6 6 0 1 X 21.4    . 18.2    . 16.1 00 00 22 00    .    .  1
16 13 44.7 86.6 05 08 98 01 0 1015.1 1 1 0 0 1 17.8    . 16.8    . 12.8 00 00 04 00    .    .  1
17 13 44.1 87.1 18 15 95 42 4 1012.3 6 6 0 7 X 19.0    . 18.3    . 17.8 18 01 14 01    .    .  1
18 07 44.0 87.5 27 06 98 02 0 1015.7 0 0 0 0 0 18.8    . 17.3    . 17.2 00 00 16 00    .    .  1
18 13 43.2 86.8 21 08 95 05 2 1017.6 4 0 0 0 1 19.8    . 16.3    . 17.8 00 00 18 00    .    .  1
22 13 43.1 86.3 24 06 98 01 0 1014.1 0 0 0 0 0 20.5    . 17.3    . 18.5 22 00 34 00    .    .  1
23 13 43.1 86.5 04 02 98 02 0 1017.8 0 0 0 0 0 20.4    . 18.1    . 18.9 04 00 09 00    .    .  1
23 19 43.1 86.4 35 14 98 02 0 1017.7 0 0 0 0 0 21.8    . 19.4    . 18.4 35 01          .    .  1
24 13 43.1 86.9 15 05 96 05 4 1021.6 1 1 0 0 1 23.6    . 20.3    . 19.0 00 00          .    .  1
25 07 42.9 87.7 03 01 97 05 4 1022.3 0 0 0 0 0 22.2    . 20.5    . 20.0 00 00          .    .  1
25 13 42.7 87.0 17 04 96 05 4 1022.5 1 1 0 0 1 22.7    . 20.6    . 20.6 00 00          .    .  1
25 19 43.0 86.3 00 00 97 05 4 1021.6 0 0 0 0 0 27.6    . 26.0    . 18.9 00 00          .    .  1
26 13 43.1 86.7 17 06 96 05 4 1022.2 0 0 0 0 0 23.0    . 20.3    . 20.0 17 00          .    .  1

                               SEPTEMBER 1963

22 13 43.1 86.3 35 07 98 03 0      . 1 1 5 0 0 13.7    . 13.4    . 07.9 32 00          .    .  1
23 19 43.0 87.0 11 08 98 03 2      . 6 6 0 3 1 15.3    . 15.9    . 08.6 18 01          .    .  1
26 13 43.1 86.5 27 02 98 02 0      . 0 0 0 0 0 17.3    . 15.9    . 13.5 00 00          .    .  1

                                OCTOBER 1963

03 12 42.3 86.4 34 19 98 03 2      . 6 6 5 X X 15.4    . 15.3    . 12.8 36 04          .    .  1
04 07 42.1 86.5 09 07 97 05 0      . 0 0 0 0 0 09.0    . 16.5    . 07.3 36 02          .    .  1
04 16 41.9 87.3 12 10 98 02 0      . 0 0 0 0 0 14.1    . 17.8    . 09.0 14 00 36 02    .    .  1
05 13 42.1 87.7 19 14 97 05 4      . 0 0 0 0 0 21.8    . 17.0    . 10.5 22 00 14 00    .    .  1
06 13 43.1 87.7 23 10 98 01 2      . 6 6 0 0 1 23.3    . 15.8    . 13.0 22 01          .    .  1
06 19 43.0 86.4 22 17 98 01 1      . 2 2 0 3 1 19.2    . 15.5    . 13.8 25 01 20 02    .    .  1
08 12 42.7 86.7 27 11 98 01 0 1017.2 0 0 0 0 0 15.8    . 15.3    . 12.0 27 00 32 01    .    .  1
08 16 42.6 86.9 00 00 98 02 0      . 0 0 0 0 0 16.3    . 16.3    . 11.3 00 00 32 00    .    .  1
08 19 42.3 87.0 15 04 98 02 0      . 0 0 0 0 0 16.7    . 16.7    . 10.8 00 00 32 00    .    .  1
08 21 41.9 87.4 14 04 98 02 0 1017.4 0 0 0 0 0 17.2    . 17.5    . 13.3 00 00 00 00    .    .  1
09 09 41.8 87.4 20 07 96 05 0      . 0 0 0 0 0 16.3    . 17.4    . 10.5 18 00          .    .  1
09 11 42.0 87.2 19 10 97 05 0 1022.2 0 0 0 0 0 15.8    . 17.3    . 10.2 18 00          .    .  1
10 09 41.8 87.5 17 12 97 05 4      . 0 0 0 0 0 17.5    . 17.3    . 09.3 18 01          .    .  1
10 13 42.0 86.7 15 11 98 03 0      . 2 2 0 0 5 19.6    . 16.3    . 12.2 14 00 18 00    .    .  1
10 19 43.0 86.2 09 08 98 03 2      . 6 6 0 0 5 20.3    . 16.3    . 09.4 09 00 14 00    .    .  1
11 13 42.8 86.7 36 18 98 02 2      . 8 8 0 0 5 15.3    . 14.5    . 13.7 36 01 32 02    .    .  1
23 19 43.1 87.0 18 12 98 03 2      . 2 2 0 0 1 18.5    . 14.8    . 12.2 22 01          .    .  1
24 13 43.1 87.5 18 12 97 01 1 1014.5 0 0 0 0 0 17.8    . 15.8    . 13.3 18 01          .    .  1
24 19 43.0 87.8 16 09 96 01 4      . 2 2 0 0 1 17.0    . 12.3    . 13.3 18 01          .    .  1
25 13 43.1 87.4 24 10 97 05 8      . 5 5 2 7 0 17.1    . 15.8    . 14.9 22 00 18 01    .    .  1
26 13 42.6 86.8 19 13 96 05 4      . 2 2 5 0 0 17.8    . 16.2    . 15.3 18 02          .    .  1
27 13 43.1 86.7 35 05 98 01 2      . 6 6 0 7 1 13.8    . 14.7    . 08.3 36 01 32 01    .    .  1
29 16 43.1 86.6 36 10 98 03 0      . 4 4 2 0 0 10.2    . 14.6    . 03.8 36 05          .    .  1
31 13 43.4 87.0 35 12 98 03 6      . 8 8 7 2 X 10.0    . 13.5    . 07.5 32 01 18 01    .    .  1
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TIMES LOCATIONS WINDS WEATHER PRESSR OKT CLOUD TEMPERATURES (DEGREES C) WAVES SWELL RADIATION V
DY HR LATD LONG DD FF VV WW W PPPPPP N A L M H AIRM AIRB WATI WATS TDPT DD HH DD HH SOLR NETR V

                                   NOVEMBER 1963

05 13 42.5 86.8 20 02 97 02 2 1008.0 8 6 6 X X 11.8  .  13.4  .  11.1 20 01         .    .   1
05 07 41.8 87.4 04 04 97 02 2 1008.9 6 8 6 X X 12.6  .  12.5  .  12.6 00 00         .    .   1
06 09 41.9 87.2 02 05 97 02 2 1010.1 8 8 6 X X 13.5  .  14.0  .  13.3 02 01         .    .   1
06 14 42.3 87.0 02 05 97 01 2 1010.0 7 7 6 X X 13.7  .  13.3  .  13.0 02 01         .    .   1
06 17 42.6 86.9 02 05 98 01 2 1011.5 4 4 5 2 0 12.2  .  13.4  .  11.8 02 01         .    .   1
07 07 42.1 86.6 34 07 97 02 0 1014.2 3 3 5 0 0 11.5  .  13.4  .  09.3 36 00         .    .   1
07 13 42.7 86.8 02 07 97 01 0      . 1 1 5 0 0 10.3  .  11.3  .  09.0 04 00         .    .   1
08 14 43.0 86.2 31 20 97 01 0 1011.5 1 1 5 0 0 10.3  .  11.7  .  08.6 31 02         .    .   1
09 13 42.3 87.2 22 25 97 01 2      . 8 8 0 7 X 12.5  .  12.1  .  09.8 22 04         .    .   1
09 19 41.8 87.5 26 13 97 05 8      . 2 2 5 0 0 14.5  .  11.5  .  10.7 26 00 18 00  .    .   1
10 14 41.9 87.4 31 11 98 03 1      . 6 6 0 3 X 13.0  .  12.4  .  05.2 31 01         .    .   1
18 21 42.7 86.8 14 04 98 01 0      . 0 0 0 0 0 09.8  .  10.0  .  09.0 00 00 32 01  .    .   1

                                     MAY 1964

02 13 43.2 87.1 08 08 97 10 4 1016.2 0 0 0 0 0 05.3  .  03.3  .  04.3 07 00         .    .   1
03 13 43.2 87.5 09 06 96 10 4 1017.3 1 0 0 0 1 08.9  .  03.9  .  05.1 09 00         .    .   1
03 20 43.0 86.3 00 00 97 05 4      . 5 5 1 0 1 11.2  .  06.0  .  08.3 14 00         .    .   1
04 19 42.2 86.4 16 06 98 01 2 1013.2 7 3 0 3 1 14.6  .  09.2  .  11.2 00 00         .    .   1
05 07 42.0 86.6 16 08 98 01 2 1016.2 7 0 0 0 1 12.2  .  07.8  .  09.8 18 00 36 00  .    .   1
05 13 42.0 87.1 18 12 98 03 2 1015.5 8 0 0 0 7 08.4  .  04.2  .  06.8 18 00 36 00  .    .   1
05 19 42.9 86.7 18 12 98 02 2 1013.7 8 0 0 0 7 08.6  .  04.0  .  06.2 18 00 36 01  .    .   1
13 08 43.2 85.5 01 10 97 60 6 1010.8 8 8 6 0 0 08.8  .  05.6  .  07.7 32 02         .    .   1
13 13 43.3 86.6 36 15 98 02 2 1015.0 8 8 5 0 0 07.3  .  07.8  .  06.8 36 02         .    .   1
14 07 43.9 86.4 00 00 98 02 0 1021.8 0 0 0 0 0 07.1  .  14.2  .  03.9 00 00         .    .   1
14 11 43.9 86.6 34 06 98 02 0      . 0 0 0 0 0 05.0  .  04.5  .  04.4 34 00 36 01  .    .   1
14 13 43.8 86.9 32 04 98 02 0 1021.8 0 0 0 0 0 04.8  .  03.9  .  04.0 32 00 36 00  .    .   1
14 15 43.8 87.0 32 01 98 02 0      . 0 0 0 0 0 05.8  .  03.8  .  04.1 00 00 36 00  .    .   1
14 18 43.6 87.5 18 04 98 02 0      . 0 0 0 0 0 05.2  .  04.8  .  04.0 18 00         .    .   1
14 20 43.7 87.6 18 04 98 02 0      . 0 0 0 0 0 07.6  .  07.3  .  04.9 18 00         .    .   1
15 12 44.4 87.4 19 20 96 10 4      . 7 7 0 7 8 09.4  .  07.2  .  07.6 19 03         .    .   1
16 07 44.4 87.3 00 00 91 45 4 1015.4 9 9 X X X 06.4  .  03.9  .  06.4 00 00 18 00  .    .   1
16 09 44.4 87.1 35 03 91 45 4 1016.0 9 9 X X X 05.2  .  03.3  .  05.2 00 00         .    .   1
16 11 44.5 86.9 36 01 91 45 4      . 9 9 X X X 05.7  .  03.8  .  05.7 00 00         .    .   1
16 14 44.5 86.6 36 01 95 10 4      . 0 0 0 0 0 06.3  .  03.9  .  05.8 00 00         .    .   1
16 18 44.6 86.3 22 03 98 02 4      . 0 0 0 0 0 07.8  .  04.0  .  07.0 00 00         .    .   1
17 13 45.0 85.9 22 07 98 03 1 1020.0 3 0 0 0 8 09.3  .  06.7  .  08.2 22 00         .    .   1
18 07 44.6 86.2 14 01 98 02 2      . 8 0 0 0 7 10.6  .  09.9  .  05.8 16 00         .    .   1
18 13 44.9 85.9 16 03 98 01 2 1021.3 6 6 0 7 7 16.8  .  10.2  .  07.5 18 00         .    .   1
19 13 44.1 86.4 26 08 98 02 0 1014.7 0 0 0 0 0 10.8  .  08.8  .  08.9 26 00 22 01  .    .   1
20 07 43.9 86.4 04 04 78 03 0 1027.7 0 0 0 0 1 06.9  .  16.3  .  04.4 04 00         .    .   1
26 08 43.0 86.2 20 12 98 02 2 1013.2 8 2 6 0 7 14.3  .  14.2  .  11.4 20 01         .    .   1
26 13 43.0 86.5 24 18 98 02 2      . 8 6 5 0 7 10.8  .  06.0  .  09.4 24 01 20 02  .    .   1
27 07 43.0 86.4 30 09 98 02 0      . 0 0 0 0 0 07.9  .  07.0  .  05.6 30 00 34 00  .    .   1
27 14 42.8 87.0 00 00 98 02 0      . 0 0 0 0 0 09.3  .  06.7  .  05.0 00 00 32 00  .    .   1
28 07 43.0 86.4 02 12 98 02 2 1019.6 7 0 0 0 7 08.2  .  06.5  .  05.3 02 00 36 00  .    .   1
28 13 42.9 87.3 03 05 98 03 2 1019.9 8 0 0 0 7 08.0  .  06.7  .  05.1 03 00 36 01  .    .   1
28 19 42.8 87.6 03 05 98 01 1      . 2 0 0 0 1 09.4  .  12.0  .  04.9 04 00         .    .   1
29 07 42.7 87.5 02 08 98 02 0      . 4 0 0 0 1 07.5  .  08.9  .  03.0 02 01         .    .   1
29 13 42.8 87.2 31 04 98 03 2      . 7 0 0 0 7 08.0  .  07.6  .  05.8 31 00 36 01  .    .   1
29 19 43.0 86.3 32 12 99 01 1 1017.8 4 0 0 0 1 11.2  .  11.0  .  05.6 32 00 36 00  .    .   1
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JUNE 1964

| TIMES | | LOCATIONS | | WINDS | | WEATHER | | | PRESSR | OKT | CLOUD | | | | TEMPERATURES (DEGREES C) | | | | | WAVES | | SWELL | | RADIATION | | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DY | HR | LATO | LONG | DD | FF | VV | WW | W | PPPPPP | N | A | L | M | H | AIRM | AIRB | WATI | WATS | TDPT | DD | HH | DD | HH | SOLR | NETR | V |
| 01 | 07 | 43.0 | 86.4 | 02 | 08 | 98 | 03 | 2 | 1020.3 | 7 | 2 | 0 | 3 | 7 | 08.1 | . | 06.9 | . | 06.9 | 36 | 00 | | | . | . | 1 |
| 01 | 13 | 43.3 | 87.1 | 35 | 09 | 98 | 01 | 0 | 1021.0 | 0 | 0 | 0 | 0 | 0 | 07.4 | . | 07.9 | . | 06.2 | 35 | 00 | 02 | 00 | . | . | 1 |
| 01 | 19 | 43.2 | 86.8 | 06 | 05 | 99 | 01 | 1 | . | 1 | 0 | 0 | 0 | 1 | 09.5 | . | 07.9 | . | 08.3 | 06 | 00 | 36 | 00 | . | . | 1 |
| 02 | 07 | 43.0 | 86.4 | 10 | 04 | 98 | 03 | 1 | . | 7 | 7 | 5 | 3 | 0 | 10.2 | . | 11.5 | . | 09.3 | 10 | 00 | | | . | . | 1 |
| 02 | 13 | 43.7 | 87.5 | 04 | 10 | 98 | 01 | 8 | . | 7 | 7 | 5 | X | X | 09.0 | . | 09.0 | . | 07.4 | 04 | 00 | | | . | . | 1 |
| 03 | 07 | 42.9 | 87.7 | 28 | 10 | 98 | 01 | 1 | 1011.8 | 4 | 4 | 5 | 3 | 0 | 11.2 | . | 11.2 | . | 08.9 | 28 | 00 | 25 | 01 | . | . | 1 |
| 03 | 13 | 42.8 | 87.0 | 29 | 05 | 97 | 02 | 0 | 1013.5 | 0 | 0 | 0 | 0 | 0 | 11.3 | . | 09.7 | . | 08.6 | 00 | 00 | | | . | . | 1 |
| 08 | 08 | 43.1 | 86.3 | 11 | 08 | 94 | 10 | 4 | 1011.4 | 9 | 9 | X | X | X | 14.4 | . | 11.9 | . | 13.8 | 14 | 00 | | | . | . | 1 |
| 08 | 10 | 43.2 | 86.6 | 10 | 10 | 93 | 47 | 4 | 1011.1 | 9 | 9 | X | X | X | 14.9 | . | 12.7 | . | 14.1 | 10 | 00 | | | . | . | 1 |
| 08 | 12 | 43.2 | 87.1 | 14 | 11 | 91 | 47 | 4 | . | 9 | 9 | X | X | X | 13.0 | . | 11.1 | . | 13.0 | 14 | 00 | | | . | . | 1 |
| 10 | 13 | 43.7 | 87.6 | 01 | 08 | 99 | 01 | 0 | . | 0 | 0 | 0 | 0 | 0 | 10.6 | . | 09.7 | . | 08.6 | 01 | 00 | 04 | 02 | . | . | 1 |
| 10 | 16 | 43.6 | 87.5 | 05 | 10 | 99 | 02 | 0 | . | 0 | 0 | 0 | 0 | 0 | 09.9 | . | 09.3 | . | 08.0 | 05 | 00 | 04 | 01 | . | . | 1 |
| 11 | 07 | 43.7 | 87.3 | 07 | 07 | 98 | 03 | 2 | . | 8 | 0 | 0 | 0 | 7 | 09.3 | . | 08.4 | . | 07.3 | 07 | 00 | | | . | . | 1 |
| 11 | 10 | 43.8 | 87.0 | 00 | 00 | 99 | 02 | 2 | . | 7 | 0 | 0 | 0 | 7 | 09.2 | . | 07.5 | . | 08.0 | 00 | 00 | | | . | . | 1 |
| 11 | 12 | 43.9 | 86.8 | 16 | 03 | 99 | 02 | 2 | . | 7 | 0 | 0 | 7 | 0 | 11.4 | . | 08.3 | . | 08.3 | 00 | 00 | | | . | . | 1 |
| 11 | 14 | 43.9 | 86.6 | 18 | 02 | 99 | 16 | 8 | . | 6 | 6 | 6 | 7 | 7 | 11.2 | . | 09.2 | . | 08.6 | 00 | 00 | | | . | . | 2 |
| 11 | 19 | 44.6 | 86.3 | 06 | 05 | 99 | 25 | 8 | 1020.2 | 7 | 7 | 6 | 7 | 7 | 12.8 | . | 11.5 | . | 10.0 | 06 | 00 | | | . | . | 2 |
| 12 | 13 | 45.0 | 85.9 | 18 | 08 | 98 | 25 | 8 | . | 8 | 8 | 6 | 7 | X | 13.9 | . | 11.3 | . | 12.0 | 18 | 00 | 16 | 00 | . | . | 1 |
| 13 | 08 | 44.6 | 86.3 | 25 | 12 | 94 | 01 | 4 | . | 1 | 0 | 0 | 0 | 1 | 11.6 | . | 11.5 | . | 11.6 | 25 | 01 | | | . | . | 1 |
| 13 | 10 | 44.5 | 86.6 | 26 | 16 | 95 | 03 | 4 | . | 2 | 0 | 0 | 0 | 1 | 09.5 | . | 08.8 | . | 08.6 | 25 | 00 | | | . | . | 1 |
| 13 | 13 | 44.5 | 86.8 | 27 | 12 | 97 | 03 | 4 | 1011.0 | 4 | 0 | 0 | 0 | 7 | 09.3 | . | 05.0 | . | 07.9 | 27 | 00 | 22 | 00 | . | . | 1 |
| 13 | 15 | 44.4 | 87.1 | 25 | 10 | 97 | 03 | 2 | . | 6 | 0 | 0 | 0 | 7 | 15.8 | . | 07.3 | . | 10.5 | 25 | 00 | | | . | . | 1 |
| 13 | 18 | 44.4 | 87.4 | 30 | 09 | 98 | 02 | 2 | . | 8 | 0 | 0 | 0 | 7 | 17.3 | . | 09.2 | . | 10.0 | 30 | 00 | | | . | . | 1 |
| 14 | 07 | 44.3 | 87.3 | 06 | 08 | 98 | 02 | 0 | 1015.9 | 0 | 0 | 0 | 0 | 0 | . | . | 11.0 | . | . | 06 | 00 | | | . | . | 1 |
| 15 | 13 | 43.9 | 86.7 | 04 | 30 | 98 | 02 | 2 | 1011.5 | 8 | 8 | 6 | X | X | 10.6 | . | 10.5 | . | 09.8 | 04 | 03 | | | . | . | 1 |
| 16 | 07 | 43.9 | 86.4 | 06 | 03 | 98 | 03 | 0 | . | 0 | | 0 | 0 | 0 | 09.4 | . | 10.3 | . | 03.3 | 06 | 00 | | | . | . | 1 |
| 17 | 07 | 42.9 | 86.2 | 09 | 15 | 98 | 02 | 2 | 1021.9 | 8 | 8 | 6 | 7 | X | 09.9 | . | 06.8 | . | 06.5 | 09 | 00 | | | . | . | 1 |
| 17 | 08 | 42.8 | 86.2 | 14 | 11 | 98 | 01 | 2 | 1020.3 | 7 | 7 | 6 | 7 | X | 11.7 | . | 08.3 | . | 07.6 | 14 | 00 | | | . | . | 1 |
| 17 | 09 | 42.8 | 86.3 | 12 | 08 | 98 | 01 | 2 | . | 6 | 6 | 0 | 7 | 0 | 12.4 | . | 10.8 | . | 09.0 | 12 | 00 | | | . | . | 1 |
| 17 | 10 | 42.8 | 86.4 | 13 | 10 | 98 | 01 | 2 | . | 5 | 0 | 0 | 0 | 7 | 13.5 | . | 11.3 | . | 10.0 | 13 | 00 | | | . | . | 1 |
| 17 | 13 | 42.8 | 87.0 | 14 | 11 | 98 | 01 | 1 | 1018.2 | 4 | 0 | 0 | 0 | 7 | 13.4 | . | 11.0 | . | 10.7 | 14 | 00 | | | . | . | 1 |
| 17 | 14 | 42.8 | 86.9 | 13 | 12 | 98 | 03 | 1 | . | 8 | 8 | 0 | 7 | X | 13.3 | . | 10.8 | . | 10.5 | 13 | 01 | | | . | . | 1 |
| 17 | 16 | 42.7 | 87.4 | 14 | 14 | 98 | 02 | 2 | . | 8 | 8 | 0 | 7 | X | 12.9 | . | 10.8 | . | 10.7 | 14 | 01 | | | . | . | 1 |
| 17 | 18 | 42.7 | 87.5 | 15 | 15 | 98 | 02 | 2 | . | 8 | 8 | 0 | 7 | X | 14.1 | . | 12.0 | . | 11.7 | 15 | 01 | | | . | . | 1 |
| 18 | 13 | 42.8 | 86.7 | 18 | 13 | 96 | 02 | 4 | 1010.0 | 0 | 0 | 0 | 0 | 0 | 14.6 | . | 11.5 | . | 13.9 | 18 | 00 | | | . | . | 1 |
| 22 | 07 | 43.0 | 86.4 | 07 | 07 | 91 | 47 | 4 | . | 9 | 9 | X | X | X | 15.4 | . | 13.4 | . | 15.4 | 00 | 00 | | | . | . | 1 |
| 22 | 13 | 42.9 | 86.7 | 12 | 08 | 96 | 02 | 4 | . | 6 | 0 | 0 | 0 | 7 | 18.9 | . | 16.6 | . | 16.1 | 00 | 00 | | | . | . | 1 |
| 22 | 19 | 43.0 | 86.3 | 34 | 04 | 98 | 95 | 9 | 1015.3 | 8 | 8 | 6 | 7 | X | 24.3 | . | 17.2 | . | 17.8 | 00 | 00 | | | . | . | 1 |
| 24 | 07 | 43.0 | 86.4 | 09 | 22 | 99 | 03 | 2 | 1009.5 | 7 | 7 | 5 | X | X | 13.5 | . | 14.5 | . | 12.9 | 29 | 04 | | | . | . | 1 |
| 24 | 13 | 43.0 | 87.7 | 34 | 09 | 99 | 02 | 0 | . | 0 | 0 | 0 | 0 | 0 | 15.2 | . | 13.5 | . | 11.6 | 34 | 00 | 32 | 01 | . | . | 1 |
| 25 | 07 | 43.0 | 87.8 | 27 | 05 | 98 | 02 | 0 | . | 3 | 3 | 0 | 3 | 0 | 17.1 | . | 13.1 | . | 14.0 | 00 | 00 | | | . | . | 1 |
| 25 | 13 | 42.9 | 87.8 | 20 | 09 | 98 | 01 | 0 | . | 0 | 0 | 0 | 0 | 0 | . | . | 15.3 | . | . | 20 | 00 | | | . | . | 1 |
| 26 | 07 | 43.0 | 87.8 | 28 | 14 | 99 | 02 | 0 | 1021.0 | 0 | 0 | 0 | 0 | 0 | 22.7 | . | 16.0 | . | 18.5 | 28 | 00 | | | . | . | 1 |
| 26 | 14 | 43.0 | 87.8 | 27 | 15 | 98 | 02 | 0 | 1019.5 | 0 | 0 | 0 | 0 | 0 | 29.2 | . | 15.1 | . | 15.6 | 27 | 00 | | | . | . | 1 |
| 27 | 07 | 43.0 | 87.7 | 36 | 06 | 98 | 03 | 0 | . | 1 | 0 | 0 | 0 | 1 | 18.0 | . | 16.0 | . | 15.4 | 36 | 00 | | | . | . | 1 |
| 27 | 13 | 43.0 | 86.6 | 32 | 07 | 98 | 03 | 0 | 1021.7 | 5 | 5 | 0 | 3 | 7 | 18.2 | . | 14.9 | 14.3 | 15.6 | 32 | 00 | | | . | . | 1 |
| 29 | 13 | 43.1 | 86.7 | 20 | 12 | 96 | 02 | 0 | . | 0 | 0 | 0 | 0 | 0 | 21.5 | . | 17.0 | 16.8 | 17.6 | 20 | 00 | | | . | . | 1 |
| 30 | 13 | 43.3 | 86.6 | 18 | 09 | 97 | 01 | 0 | 1019.2 | 0 | 0 | 0 | 0 | 0 | 20.5 | . | 16.8 | 16.9 | 17.1 | 18 | 00 | | | . | . | 1 |

JULY 1964

| TIMES | | LOCATIONS | | WINDS | | WEATHER | | | PRESSR | OKT | CLOUD | | | | TEMPERATURES (DEGREES C) | | | | | WAVES | | SWELL | | RADIATION | | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DY | HR | LATD | LONG | DD | FF | VV | WW | W | PPPPPP | N | A | L | M | H | AIRM | AIRB | WATI | WATS | TDPT | DD | HH | DD | HH | SOLR | NETR | V |
| 01 | 13 | 42.7 | 86.4 | 20 | 03 | 96 | 01 | 2 | 1016.9 | 6 | 0 | 0 | 0 | 7 | 19.9 | . | 18.7 | 18.8 | 19.5 | 20 | 00 | | | . | . | 1 |
| 02 | 13 | 42.9 | 86.5 | 28 | 08 | 96 | 01 | 0 | . | 0 | 0 | 0 | 0 | 0 | 20.8 | . | 19.3 | . | 20.1 | 28 | 00 | | | . | . | 1 |
| 06 | 07 | 43.1 | 86.3 | 12 | 11 | 98 | 02 | 2 | . | 7 | 0 | 0 | 0 | 7 | 17.0 | . | 12.7 | 12.0 | 11.0 | 12 | 00 | | | 0.25 | . | 1 |
| 06 | 13 | 43.1 | 86.6 | 15 | 21 | 98 | 02 | 8 | 1014.0 | 7 | 7 | 6 | 7 | X | 16.5 | . | 17.3 | 17.2 | 15.7 | 15 | 01 | | | 0.30 | . | 1 |
| 07 | 13 | 45.2 | 85.4 | 04 | 06 | 98 | 02 | 2 | . | 8 | 8 | 6 | X | X | 17.2 | . | 16.2 | 16.0 | 16.5 | 04 | 00 | | | 0.55 | . | 1 |
| 08 | 13 | 45.7 | 85.1 | 06 | 06 | 98 | 03 | 0 | 1015.6 | 4 | 0 | 0 | 0 | 1 | 20.5 | . | 17.6 | 17.8 | 15.7 | 06 | 00 | | | 1.10 | . | 1 |
| 09 | 12 | 45.8 | 85.2 | 26 | 08 | 97 | 02 | 0 | . | 0 | 0 | 0 | 0 | 0 | 19.4 | . | 18.5 | 18.8 | 15.8 | 26 | 00 | | | 1.28 | . | 1 |
| 09 | 19 | 45.7 | 85.2 | 28 | 05 | 97 | 02 | 0 | . | 0 | 0 | 0 | 0 | 0 | 22.3 | . | 19.8 | 19.7 | 17.2 | 28 | 00 | | | 0.21 | . | 1 |
| 10 | 13 | 44.9 | 86.0 | 29 | 09 | 97 | 02 | 0 | . | 0 | 0 | 0 | 0 | 0 | 19.2 | . | 17.8 | 18.2 | 16.2 | 29 | 00 | | | 1.27 | . | 1 |
| 11 | 13 | 44.8 | 86.4 | 26 | 12 | 97 | 05 | 1 | . | 8 | 0 | 1 | 0 | 7 | 18.8 | . | 18.5 | 19.0 | 17.2 | 02 | 00 | | | 0.50 | . | 1 |
| 14 | 07 | 44.6 | 86.3 | 35 | 10 | 92 | 46 | 4 | 1015.0 | 8 | 8 | 5 | X | X | 10.0 | . | 06.6 | 06.5 | 09.7 | 35 | 00 | | | 0.44 | . | 1 |
| 14 | 09 | 44.6 | 86.3 | 35 | 10 | 92 | 46 | 4 | 1006.8 | 8 | 8 | 5 | X | X | 11.7 | . | 09.5 | 09.0 | 11.7 | 35 | 00 | | | 0.33 | . | 1 |
| 14 | 13 | 44.5 | 86.6 | 36 | 11 | 98 | 02 | 4 | 1010.0 | 8 | 8 | 5 | X | X | 14.3 | . | 14.3 | 14.3 | 13.8 | 36 | 00 | | | 1.15 | . | 1 |
| 14 | 15 | 44.5 | 86.9 | 34 | 10 | 98 | 01 | 1 | 1011.3 | 4 | 4 | 1 | 0 | 0 | 14.3 | . | 14.0 | 13.8 | 13.4 | 36 | 01 | | | 1.02 | . | 1 |
| 14 | 17 | 44.4 | 87.1 | 00 | 00 | 98 | 01 | 1 | . | 0 | 0 | 0 | 0 | 0 | 16.2 | . | 15.3 | 15.0 | 14.5 | 00 | 00 | | | 0.23 | . | 1 |
| 14 | 19 | 44.1 | 87.3 | 18 | 07 | 98 | 03 | 1 | . | 3 | 3 | 1 | 0 | 0 | 16.0 | . | 15.3 | 15.2 | 14.5 | 18 | 00 | | | 0.23 | . | 1 |
| 15 | 08 | 43.6 | 87.5 | 16 | 07 | 96 | 02 | 4 | . | 0 | 0 | 0 | 0 | 0 | 16.0 | . | 14.7 | 14.6 | 15.8 | 16 | 00 | | | 0.46 | . | 1 |
| 15 | 12 | 43.8 | 87.0 | 20 | 10 | 96 | 02 | 4 | 1019.0 | 0 | 0 | 0 | 0 | 0 | 16.3 | . | 15.4 | 15.3 | 16.0 | 20 | 00 | | | 1.27 | . | 1 |
| 15 | 14 | 43.9 | 86.8 | 19 | 08 | 96 | 02 | 4 | . | 0 | 0 | 0 | 0 | 0 | 16.3 | . | 15.3 | 15.1 | 15.7 | 20 | 00 | | | 1.29 | . | 1 |
| 15 | 16 | 43.9 | 86.5 | 20 | 08 | 97 | 02 | 4 | 1019.2 | 0 | 0 | 0 | 0 | 0 | 17.0 | . | 11.7 | 11.0 | 15.6 | 20 | 00 | | | 0.93 | . | 1 |
| 16 | 08 | 43.6 | 86.6 | 18 | 15 | 97 | 05 | 0 | . | 0 | 0 | 0 | 0 | 0 | 18.0 | . | 11.3 | 11.0 | 15.8 | 18 | 00 | | | 0.45 | . | 1 |
| 16 | 11 | 43.2 | 86.5 | 15 | 11 | 95 | 10 | 4 | . | 0 | 0 | 0 | 0 | 0 | 18.2 | . | 16.5 | 16.4 | 17.9 | 15 | 00 | 20 | 00 | 1.04 | . | 1 |
| 16 | 12 | 43.1 | 86.3 | 15 | 12 | 96 | 05 | 4 | . | 0 | 0 | 0 | 0 | 0 | 18.4 | . | 15.8 | 15.8 | 16.1 | 15 | 00 | | | 1.21 | . | 1 |
| 27 | 07 | 42.9 | 86.2 | 13 | 07 | 98 | 03 | 0 | 1015.3 | 2 | 0 | 0 | 0 | 1 | 18.7 | . | 20.6 | 21.9 | 17.0 | 13 | 00 | | | 0.22 | . | 1 |
| 77 | 08 | 42.8 | 86.2 | 22 | 14 | 98 | 03 | 0 | . | 3 | 0 | 0 | 0 | 1 | 21.8 | . | 22.4 | 22.0 | 19.0 | 22 | 00 | | | 0.40 | . | 1 |
| 27 | 09 | 42.8 | 86.3 | 22 | 11 | 98 | 02 | 0 | . | 2 | 0 | 0 | 0 | 1 | 22.9 | . | 22.8 | 22.4 | 21.0 | 22 | 00 | | | 0.64 | . | 1 |
| 27 | 10 | 42.8 | 86.4 | 20 | 10 | 97 | 01 | 0 | . | 2 | 0 | 0 | 0 | 1 | 23.7 | . | 22.8 | 23.8 | 22.0 | 20 | 00 | | | 0.89 | . | 1 |
| 27 | 13 | 42.8 | 86.7 | 20 | 09 | 97 | 03 | 0 | . | 3 | 0 | 0 | 0 | 1 | 23.3 | . | 22.4 | 22.1 | 22.1 | 20 | 00 | | | 1.23 | . | 1 |
| 27 | 15 | 42.8 | 86.9 | 16 | 08 | 97 | 03 | 1 | 1014.5 | 5 | 0 | 0 | 0 | 7 | 24.5 | . | 22.8 | 22.7 | 22.2 | 16 | 00 | | | 0.98 | . | 1 |
| 27 | 17 | 42.7 | 87.4 | 15 | 12 | 97 | 03 | 1 | . | 5 | 0 | 0 | 0 | 7 | 24.8 | . | 22.6 | 23.5 | 22.3 | 15 | 00 | 18 | 02 | 0.74 | . | 1 |
| 27 | 18 | 42.7 | 87.5 | 16 | 12 | 96 | 02 | 2 | . | 7 | 0 | 0 | 0 | 7 | 24.5 | . | . | 22.5 | 21.8 | 16 | 00 | 18 | 03 | 0.10 | . | 1 |
| 28 | 07 | 42.7 | 87.6 | 20 | 04 | 97 | 02 | 2 | . | 7 | 0 | 0 | 0 | 7 | 21.7 | . | 18.8 | 18.5 | 20.0 | 20 | 00 | | | 0.14 | . | 1 |
| 28 | 13 | 42.9 | 86.6 | 20 | 07 | 96 | 15 | 3 | . | 4 | 0 | 0 | 0 | 1 | 24.0 | . | 22.9 | 22.9 | 22.6 | 20 | 00 | | | 1.25 | . | 1 |
| 30 | 13 | 43.0 | 86.3 | 28 | 05 | 98 | 80 | 8 | 1013.0 | 8 | 8 | 0 | 7 | 7 | 17.2 | . | 18.5 | 18.2 | 11.6 | 28 | 00 | | | 0.33 | . | 1 |
| 30 | 19 | 43.0 | 86.2 | 01 | 11 | 98 | 02 | 3 | . | 7 | 7 | 0 | 7 | X | 18.8 | . | 19.5 | 19.6 | 13.9 | 36 | 00 | | | 0.06 | . | 1 |
| 31 | 07 | 43.0 | 86.3 | 10 | 07 | 98 | 02 | 3 | . | 8 | 8 | 0 | 7 | X | 15.9 | . | 14.2 | . | 11.0 | 10 | 00 | | | 0.08 | . | 1 |
| 31 | 13 | 42.7 | 86.5 | 15 | 13 | 98 | 02 | 3 | . | 8 | 8 | 0 | 7 | X | 21.0 | . | 19.8 | 19.7 | 15.1 | 15 | 02 | | | 0.25 | . | 1 |

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TIMES LOCATIONS WINDS WEATHER PRESSR OKT CLOUD TEMPERATURES (DEGREES C) WAVES SWELL RADIATION V
DY HR LATD LONG DD FF VV WW W PPPPPP N A L M H AIRM AIRB WATI WATS TDPT DD HH DD HH SOLR NETR V

                                       AUGUST 1964

03 06 43.0 86.2 30 06 98 02 3 1010.0 7 7 5 7 7 24.0   .     .  20.0 21.9 30 00 22 01 0.01  .   1
03 13 43.5 86.9 34 14 98 02 0 1012.0 0 0 0 0 0 22.0   .  20.8 20.4 21.1 34 00 22 01 1.25  .   1
04 07 44.0 86.5 33 10 96 10 4 1016.7 5 0 0 0 7 20.8   .  20.2 20.2 20.5 33 00       0.30  .   1
04 13 44.2 86.3 32 09 98 02 2 1018.0 5 0 0 0 7 21.1   .  19.9 19.8 18.0 34 00       1.41  .   1
05 07 43.9 86.6 04 09 98 02 0 1022.5 0 0 0 0 0 18.0   .  19.6 19.5 15.5 04 00       0.15  .   1
05 13 44.3 87.3 04 11 98 02 0 1024.0 0 0 0 0 0 19.5   .  20.8 20.8 16.2 04 01       1.22  .   1
05 19 43.8 87.5 04 12 98 02 0 1023.0 0 0 0 0 0 24.0   .  21.0 21.0 15.5 04 02       0.22  .   1
06 07 43.7 87.6 16 10 98 02 0 1021.0 3 0 0 0 1 20.8   .  18.7 18.0 18.5 16 01       0.10  .   1
06 14 43.3 86.7 18 12 98 02 1 1020.2 5 0 0 0 7 20.3   .  20.5 20.5 15.2 18 02       1.10  .   1
10 06 43.0 86.2 11 04 98 80 2 1016.0 8 8 0 7 X 13.6   .  20.5   .  00.0 11 00       0.00  .   1
10 08 43.2 86.5 15 06 98 02 2 1015.0 8 8 0 7 X 14.5   .  17.2 17.3 11.4 15 00       0.01  .   1
10 13 43.5 86.7 17 16 98 02 2      . 8 8 5 7 X 18.5   .  19.7 19.8 15.0 18 02 18 02 0.50  .   1
10 20 44.5 86.3 13 08 98 01 1 1008.0 3 3 0 1 7 18.7   .  18.2 18.5 15.0 13 00 18 01 0.02  .   1
11 07 44.7 86.2 19 11 97 05 9 0999.0 8 8 5 1 X 20.1   .  17.9 18.0 17.6 19 00 18 01 0.05  .   1
13 12 45.2 85.2 31 17 99 01 2 1016.2 6 6 1 0 0 13.1   .  17.9 17.8 08.0 29 01       0.45  .   1
14 06 45.0 85.9 29 04 98 02 0 1018.8 0 0 0 0 0 15.6   .  17.2 17.2 10.1 29 00       0.04  .   1
14 13 44.9 86.8 30 01 99 02 0      . 0 0 0 0 0 17.7   .  18.3 18.1 09.7 30 00       1.20  .   1
15 07 44.6 86.3 15 07 97           . 4 4 5 0 0 11.9 11.3 09.5 09.2 11.0 15 00 22 00 0.07  .   1
15 11 44.6 86.3 18 05 97 05   1018.0 3 0 0 0 1 16.9 17.9 16.7 16.7 14.9 18 00 22 00 1.06  .   1
15 13 44.5 86.6 21 08 97           . 6 0 0 0 5 17.8 18.7 17.7 17.6 13.7 22 00       1.20  .   1
15 17 44.5 86.9 20 17 97           . 6 6 5 5 1 19.2 19.0 17.7 17.9 12.3 20 02       0.45  .   1
16 07 44.4 87.4 25 12 98           . 8 8 5 X X 16.5 16.3 12.7 12.8 10.7 22 00 18 00 0.00  .   1
16 08 44.4 87.4 24 09 98      1012.8 8 8 5 X X 16.8 16.9 14.3 14.1 12.0 25 00 20 00 0.07  .   1
16 13 44.4 87.3 25 04 98           . 4 4 2 0 0 19.0 19.4 17.7 17.8 15.2 27 00 18 01 0.78  .   1
17 07 44.4 87.4 03 04 98           . 0 0 0 0 0 14.3 14.4 15.8   .  14.2 00 00 18 01 0.16  .   1
17 13 44.0 86.5 30 09 98      1014.8 0 0 0 0 0 18.5 19.8 18.5 18.4 16.6 29 00       1.22  .   1
17 14 43.9 86.6 33 05 98           . 1 1 2 0 0 19.3 19.6 19.3 18.9 16.1 33 00       1.15  .   1
17 16 43.9 86.5 01 13 98           . 3 3 2 3 0 17.6 17.8 16.3 16.9 16.0 04 01       0.79  .   1
18 07 43.9 86.6 04 05 97           . 3 3 5 0 0 13.5   .  15.8   .  12.0 04 00 36 00 0.11  .   1
18 09 43.9 86.8 05 07 99           . 6 6 5 3 0 16.2 16.4 18.6 18.4 13.5 04 00       0.21  .   1
18 11 43.8 87.0 02 11 99           . 5 5 0 3 0 17.0 17.5 18.7 18.6 10.6 02 01       1.16  .   1
18 13 43.6 87.4 01 08 99           . 5 5 5 3 0 17.1 17.7 19.6 19.3 10.6 04 01       1.20  .   1
18 15 43.7 87.6 08 07 99           . 4 4 5 3 0 17.1 17.7 19.8 19.8 11.5 07 00 02 00 0.88  .   1
19 07 43.7 87.5 11 03 99      1018.2 7 7 5 0 0 17.4 17.3 19.7 19.4 12.1 10 00 04 02 0.14  .   1
19 13 43.3 86.6 17 02 99           . 7 7 5 3 0 17.5 17.4 18.6 18.8 10.7 19 02       0.65  .   1
20 07 42.9 86.2 18 05 95 62   1011.9 8 8 6 X X 16.4 16.7 17.6 17.5 16.3 20 01       0.04  .   1
20 08 42.8 86.2 18 07 97 05        . 8 8 0 5 X 17.5 17.6 18.0 18.0 16.1 18 01       0.15  .   1
20 10 42.8 86.4 15 08 97 05   1014.0 8 3 5 5 X 17.7   .  17.7 17.8 17.4 15 02       0.28  .   1
20 13 42.8 86.9 15 16 98      1014.2 8 8 0 5 1 19.8   .  19.5 19.4 16.6 15 02       0.94  .   1
20 15 42.7 87.4 11 10 98           . 8 4 2 2 X 20.5   .  19.5 19.5 17.4 15 02       0.59  .   1
20 16 42.7 87.5 11 09 98           . 8 8 2 2 X 20.4   .  20.2 20.2 17.7 15 02       0.29  .   1
20 17 42.7 87.7 09 10 98           . 8 8 2 2 X 20.3   .  19.8   .  17.9 15 02       0.18  .   1
22 07 42.7 87.6 17 06 97 05   1006.8 2 2 0 5 0 20.2 20.2 19.1 19.2 20.2 16 00       0.10  .   1
22 13 42.9 86.7 16 08 96 05   1005.7 7 1 0 2 5 19.4 19.4 18.4 18.3 19.1 16 00       0.69  .   1
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TIMES LOCATIONS WINDS WEATHER PRESSR OKT CLOUD TEMPERATURES (DEGREES C) WAVES SWELL RADIATION V
DY HR LATD LONG DD FF VV WW W PPPPPP N A L M H AIRM AIRB WATI WATS TDPT DD HH DD HH SOLR NETR V

                                 SEPTEMBER 1964

10 07 43.1 86.3 18 13 97 05   1013.2 8 5 0 5 1 20.8 21.3 19.3 19.2 19.0 22 01       0.06    . 1
10 08 43.1 86.3 20 14 97 05        . 8 8 0 5 X 21.3 21.7 19.5 19.4 19.0 22 02       0.05    . 1
10 09 43.2 86.5 21 15 97 05          8 8 0 5 X 22.0    . 19.5 19.4 19.4 22 02       0.13    . 1
10 13 43.6 86.5 18 12 96 62   1011.3 8 3 3 5 X 20.2    . 18.4 18.3 19.2 20 01       0.09    . 1
10 19 44.5 86.2 34 06 98           . 4 4 1 2 1 18.9    . 18.1 18.4 15.6 20 00       0.00    . 1
12 13 45.1 85.8 27 11 98      1024.3 2 2 5 0 0 12.0    . 16.4    . 01.6 29 01       1.08    . 1
15 08 45.3 85.3 10 08 98      1027.4 4 4 5 0 0 08.1    . 16.1    . 02.5 00 01       0.13    . 1
15 10 45.4 85.4 36 07 98           . 2 2 5 0 0 08.5    . 16.1    . 02.2 00 00       0.40    . 1
15 11 45.5 85.5 02 07 98           . 1 1 5 0 0 08.3    . 15.9 15.6 01.5 00 00       1.00    . 1
15 13 45.3 85.7 36 07 98           . 3 3 5 0 0 08.9    . 16.0 15.9 02.9 00 00       1.04    . 1
15 19 44.7 86.2 02 10 98      1025.8 1 0 0 0 1 10.8    . 16.0    . 01.3 36 01       0.00    . 1
16 07 44.6 86.3 16 13 98           . 8 0 0 0 7 10.0    . 14.2    . 06.0 16 01          .    . 1
16 09 44.6 86.3 16 18 98           . 8 6 5 3 1 11.8    . 15.7    . 06.0 16 03          .    . 1
16 13 44.5 86.6 20 18 98           . 7 7 0 5 0 14.9    . 16.3    . 09.0 18 04          .    . 1
16 16 44.5 86.9 18 18 98           . 3 3 0 3 1 15.0    . 16.0    . 11.0 18 03          .    . 1
16 19 44.4 87.1 18 12 98           . 7 7 0 5   14.0    . 12.5    . 12.0 18 02          .    . 1
17 07 44.4 87.4 22 07 96 05        . 0 0 0 0 0 15.3    . 13.5    . 13.0 18 01          .    . 1
17 13 44.2 87.1 20 08 97 05        . 3 0 0 0 1 18.9    . 17.9    . 16.0 18 00          .    . 1
17 17 43.9 86.6 18 05 96 05        . 7 0 0 0 7 19.0    . 17.9    . 17.0 20 00          .    . 1
17 19 43.9 86.5 18 03 96 05        . 6 1 0 1 0 16.6    . 15.9    . 16.0 20 00          .    . 1
18 07 43.9 86.6 18 12 96 05        . 8 8 5 2 X 18.3    . 17.3    . 16.0 18 00          .    . 1
18 08 43.9 86.8 18 07 97 60        . 8 8 5 2 X 17.9    . 17.2    . 16.0 18 00          .    . 1
18 10 43.8 87.0 17 13 97 60 6      . 8 8 0 2 X 17.7    . 17.9    . 16.0 18 01          .    . 1
18 13 43.6 87.5 20 17 97 60 6      . 8 8 6 2 X 16.7    . 16.5    . 16.0 16 03          .    . 1
18 16 43.7 87.6 13 17 97 05 6      . 8 8 5 2 X 15.1    . 12.1    . 14.0 14 04          .    . 1
19 07 43.8 87.6 12 03 92 45 4      . 9 9 X X X 13.9    . 12.6    . 13.9 14 02          .    . 1
19 13 43.5 86.8 16 06 97 05        . 8 8 5 X X 18.1    . 17.8    . 16.0 16 02          .    . 1
29 13 43.1 86.4 24 06 98           . 0 0 0 0 0 13.2    . 16.0 16.0 07.0 00 00       0.94    . 1
30 13 43.1 86.3 00 00              . 0 0 0 0 0 12.1    . 15.9 16.0 05.0 34 00       0.97    . 1

                                  OCTOBER 1964

05 07 43.0 86.2 04 11 98           . 7 7 5 X X 06.4    . 14.7    . 02.9 32 03       0.00    . 1
06 07 43.1 86.3 06 10 98           . 7 7 5 X X 03.1    . 14.0 13.9 01.3 32 02       0.00    . 1
06 13 44.0 86.5 34 11 98           . 7 7 5 3 X 04.3    . 12.8 12.8 05.9 32 01       0.65    . 1
07 07 44.7 86.2 16 02 98           . 8 8 1 5 X 03.5    . 13.2 13.2 03.5 18 03       0.01    . 1
07 13 45.2 85.5 16 26 98           . 8 8 0 2 X 06.6    . 13.3    . 01.9 15 04       0.12    . 1
08 13 45.3 85.2 20 08 97 05        . 8 8 5 X X 10.9    . 13.6    . 07.5 22 00       0.06    . 1
11 07 45.3 85.3 19 15 98           . 2 1 5 0 1 03.3    . 12.9    . 01.1 20 01       0.02    . 1
11 09 45.4 85.4 20 15 98           . 7 7 5 X X 06.0    . 12.8    . 01.1 20 03       0.20    . 1
11 10 45.5 85.5 20 15 98           . 7 7 5 X X 06.6    . 12.8    . 01.3 20 03       0.09    . 1
11 13 45.5 85.1 22 16 98           . 8 8 5 X X 07.5    . 12.1    . 01.2 22 03       0.33    . 1
12 07 45.2 85.4 24 16 98      1019.0 8 8 0 5 X 10.4    . 12.4 12.1 04.5 22 03       0.00    . 1
12 13 44.6 86.3 23 14 97 05   1019.5 6 2 0 5 1 10.5    . 11.8 11.9 04.1 22 02       0.70    . 1
12 14 44.6 86.3 23 14 97 05        . 7 6 0 5 1 10.5    . 11.7    . 04.8 22 01       0.42    . 1
12 16 44.6 86.3 22 15 97 05          6 0 0 0 1 10.8    . 11.5    . 04.8 22 01       0.31    . 1
13 07 44.5 86.4 29 05 97 05   1020.0 5 1 0 1 1 10.5    . 11.4 11.5 07.9 22 00       0.00    . 1
13 10 44.5 86.6 29 05 98 05   1021.5 4 0 0 0 1 09.7    . 11.2    . 07.4 30 00       0.42    . 1
13 12 44.5 86.9 27 05 91 45 4      . 9 9 X X X 06.8    . 09.5 09.5 06.4 29 00       0.55    . 1
13 13 44.4 87.0 27 07 91 45 4 1022.2 9 9 X X X 07.1    . 09.3    . 06.0 29 00       0.34    . 1
13 15 44.4 87.1 18 04 96 05   1022.2 0 0 0 0 0 09.7    . 09.7    . 07.2 00 00       0.62    . 1
14 07 44.4 87.4 23 10 96 10   1022.4 0 0 0 0 0 07.6    . 08.7    . 05.7 18 00       0.05    . 1
14 13 43.7 87.4 18 10 96 05   1021.8 0 0 0 0 0 10.1    . 09.4    . 07.7 18 00       0.87    . 1
14 15 43.6 87.5 17 10 96 05        . 0 0 0 0 0 11.4    . 09.8    . 07.9 18 00       0.60    . 1
14 16 43.6 87.6 17 04 94 10   1020.5 0 0 0 0 0 09.9    . 07.2 06.9 07.3 18 00       0.45    . 1
15 07 43.7 87.5 21 07 96 10 4 1019.3 0 0 0 0 0 09.4    . 09.0 09.1 05.7 18 00       0.01    . 1
15 09 43.8 87.0 21 08 96 10 4 1018.2 0 0 0 0 0 11.2    . 11.2 11.3 07.7 18 00       0.31    . 1
15 12 43.9 86.8 20 08 96 05 4      . 0 0 0 0 0 12.0    . 10.9 11.2 08.4 20 00       0.76    . 1
15 13 43.9 86.6 20 10 96 05   1017.0 0 0 0 0 0 12.7    . 11.7 11.8 09.1 20 00       0.62    . 1
15 15 43.9 86.5 20 10 96 05        . 0 0 0 0 0 13.6    . 11.9    . 09.7 20 01       0.64    . 1
16 07 43.9 86.5 16 10 96 05   1013.8 0 0 0 0 0 11.6    . 11.4    . 08.3 20 00       0.00    . 1
16 13 43.4 86.5 16 06 96 05   1012.5 0 0 0 0 0 14.3    . 13.5    . 11.0 18 00       0.86    . 1
16 15 43.2 86.5 22 03 97 05        . 0 0 0 0 0 14.1    . 13.9    . 11.3 00 00       0.60    . 1
16 16 43.1 86.3 00 00 97 05   1011.2 0 0 0 0 0 14.2    . 13.7    . 10.2 00 00       0.41    . 1
```

| TIMES | | LOCATIONS | | WINDS | | WEATHER | | | PRESSR | OKT | CLOUD | | | | TEMPERATURES | (DEGREES C) | | | | WAVES | | SWELL | | RADIATION | | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DY | HR | LATD | LONG | DD | FF | VV | WW | W | PPPPPP | N | A | L | M | H | AIRM | AIRB | WATI | WATS | TDPT | DD | HH | DD | HH | SOLR | NETR | V |

### NOVEMBER 1964

| DY | HR | LATD | LONG | DD | FF | VV | WW | W | PPPPPP | N | A | L | M | H | AIRM | AIRB | WATI | WATS | TDPT | DD | HH | DD | HH | SOLR | NETR | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 04 | 07 | 43.1 | 86.3 | 16 | 10 | 96 | 05 | | 1023.0 | 0 | 0 | 0 | 0 | 0 | 13.0 | . | 12.2 | . | . | 20 | 00 | | | 0.00 | . | 1 |
| 04 | 13 | 44.1 | 86.6 | 18 | 15 | 96 | 05 | | 1020.5 | 4 | 0 | 0 | 0 | 1 | 12.4 | . | 11.0 | . | 08.3 | 18 | 01 | | | 0.52 | . | 1 |
| 04 | 19 | 44.6 | 86.2 | 31 | 11 | 96 | 60 | | 1021.1 | 8 | 8 | 0 | 2 | X | 10.8 | . | 10.0 | . | 08.6 | 20 | 02 | | | 0.00 | . | 1 |
| 05 | 07 | 44.7 | 86.2 | 32 | 18 | 98 | | | 1024.4 | 8 | 8 | 5 | X | X | 07.5 | . | 10.0 | . | 01.6 | 34 | 03 | | | 0.00 | . | 1 |
| 05 | 13 | 45.0 | 86.0 | 34 | 09 | 98 | | | 1024.0 | 8 | 8 | 5 | X | X | 07.2 | . | 10.7 | . | 01.4 | 34 | 00 | | | 0.30 | . | 1 |
| 05 | 19 | 45.0 | 85.9 | 28 | 06 | 98 | | | 1023.9 | 7 | 7 | 5 | X | X | 07.2 | . | 11.2 | . | 01.2 | 30 | 01 | | | 0.00 | . | 1 |
| 06 | 07 | 45.3 | 85.3 | 22 | 11 | 98 | | | 1019.4 | 2 | 2 | 5 | 0 | 0 | 06.1 | . | 11.1 | . | 03.5 | 15 | 01 | | | 0.00 | . | 1 |
| 06 | 09 | 45.4 | 85.4 | 21 | 18 | 98 | | | . | 3 | 3 | 5 | 0 | 0 | 07.6 | . | 11.2 | . | 04.1 | 22 | 03 | | | 0.08 | . | 1 |
| 06 | 10 | 45.5 | 85.5 | 21 | 23 | 98 | | | 1017.9 | 3 | 3 | 5 | 0 | 0 | 09.2 | . | 10.9 | . | 04.7 | 23 | 04 | | | 0.38 | . | 1 |
| 06 | 13 | 45.2 | 85.8 | 24 | 22 | 96 | 05 | | . | 8 | 8 | 6 | X | X | 07.0 | . | 11.3 | . | 03.8 | 23 | 04 | | | 0.18 | . | 1 |
| 06 | 18 | 44.6 | 86.3 | 24 | 10 | 98 | | | . | 8 | 8 | 6 | X | X | 08.0 | . | 10.0 | . | 04.8 | 23 | 02 | | | 0.00 | . | 1 |
| 07 | 07 | 44.6 | 86.3 | 15 | 04 | 98 | | | 1019.3 | 8 | 8 | 5 | X | X | 08.1 | . | 09.7 | . | 04.0 | 16 | 00 | | | 0.00 | . | 1 |
| 07 | 11 | 44.5 | 86.6 | 26 | 06 | 98 | | | 1019.8 | 8 | 8 | 5 | X | X | 09.8 | . | 10.1 | . | 03.3 | 20 | 00 | | | 0.17 | . | 1 |
| 07 | 13 | 44.5 | 86.9 | 26 | 05 | 98 | | | 1018.5 | 8 | 8 | 5 | X | X | 10.1 | . | 10.3 | . | 03.7 | 20 | 00 | | | 0.24 | . | 1 |
| 07 | 15 | 44.4 | 87.1 | 17 | 07 | 97 | 05 | | . | 6 | 6 | 5 | X | X | 10.0 | . | 10.0 | 09.8 | 06.5 | 20 | 00 | | | 0.28 | . | 1 |
| 07 | 17 | 44.4 | 87.4 | 17 | 07 | 96 | 05 | | 1017.8 | 6 | 6 | 5 | X | X | 09.5 | . | 09.3 | . | 06.1 | 00 | 00 | | | 0.04 | . | 1 |
| 08 | 07 | 44.3 | 87.5 | 25 | 07 | 95 | 10 | | 1017.9 | 8 | 8 | 6 | X | X | 05.4 | . | 08.8 | . | 03.1 | 25 | 00 | | | 0.00 | . | 1 |
| 08 | 13 | 44.2 | 86.3 | 22 | 10 | 91 | 45 | 4 | 1018.4 | 9 | 9 | X | X | X | 08.7 | . | 10.5 | . | 06.2 | 23 | 01 | | | 0.15 | . | 1 |
| 08 | 16 | 43.9 | 86.6 | 20 | 08 | 91 | 45 | 4 | 1017.9 | 9 | 9 | X | X | X | 08.0 | . | 11.0 | . | 05.9 | 23 | 01 | | | 0.10 | . | 1 |
| 08 | 17 | 43.9 | 86.5 | 19 | 11 | 91 | 45 | 4 | . | 9 | 9 | X | X | X | 08.5 | . | 10.7 | . | 06.4 | 23 | 01 | | | 0.00 | . | 1 |
| 09 | 07 | 43.9 | 86.6 | 18 | 08 | 96 | 05 | | 1016.8 | 8 | 8 | 5 | X | X | 11.4 | . | 10.7 | . | 08.6 | 23 | 00 | | | 0.00 | . | 1 |
| 09 | 08 | 43.9 | 86.8 | 18 | 08 | 96 | 05 | | . | 6 | 6 | 5 | 3 | 9 | 10.0 | . | 10.7 | . | 08.0 | 23 | 01 | | | 0.03 | . | 1 |
| 09 | 11 | 43.8 | 87.0 | 19 | 12 | 96 | 05 | | 1016.0 | 0 | 0 | 0 | 0 | 0 | 10.5 | . | 09.1 | . | 07.4 | 20 | 01 | | | 0.53 | . | 1 |
| 09 | 13 | 43.6 | 87.4 | 18 | 15 | 96 | 05 | | 1012.9 | 0 | 0 | 0 | 0 | 0 | 10.7 | . | 09.6 | . | 07.2 | 18 | 02 | | | 0.63 | . | 1 |
| 09 | 16 | 43.7 | 87.6 | 19 | 12 | 96 | 05 | | 1010.3 | 1 | 1 | 5 | 0 | 0 | 10.2 | . | 07.5 | . | 06.2 | 18 | 02 | | | 0.17 | . | 1 |
| 10 | 13 | 43.6 | 87.0 | 34 | 08 | 96 | 05 | | 1014.5 | 8 | 8 | 5 | X | X | 09.5 | . | 09.6 | . | 07.0 | 02 | 03 | | | 0.29 | . | 1 |

### MARCH 1965

| DY | HR | LATD | LONG | DD | FF | VV | WW | W | PPPPPP | N | A | L | M | H | AIRM | AIRB | WATI | WATS | TDPT | DD | HH | DD | HH | SOLR | NETR | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 15 | 43.0 | 86.2 | 33 | 16 | | | | . | | | | | | . | -3.5 | 00.3 | . | -8.4 | | | | | 0.87 | . | 2 |
| 26 | 13 | 42.8 | 86.4 | | | | | | . | | | | | | . | -3.8 | 00.0 | . | -7.9 | | | | | 0.72 | . | 2 |

### APRIL 1965

| DY | HR | LATD | LONG | DD | FF | VV | WW | W | PPPPPP | N | A | L | M | H | AIRM | AIRB | WATI | WATS | TDPT | DD | HH | DD | HH | SOLR | NETR | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 08 | 13 | 42.1 | 87.2 | 24 | 08 | 96 | | | . | 8 | 8 | 0 | 3 | X | 03.1 | 03.4 | 01.3 | . | -2.7 | 13 | 01 | | | 0.34 | . | 2 |
| 15 | 13 | 41.9 | 87.5 | | | 97 | | | . | 8 | | | | | 09.7 | 09.0 | 04.3 | . | 00.3 | 00 | 00 | | | 0.22 | . | 2 |
| 16 | 13 | 42.7 | 87.6 | 07 | 05 | 97 | | | . | 8 | | | | | 01.7 | 01.8 | 02.3 | . | -7.5 | 02 | 01 | | | 0.43 | . | 2 |
| 16 | 14 | 42.7 | 87.5 | 36 | 05 | 98 | | | . | 8 | 8 | 0 | 3 | X | 01.7 | 01.8 | 02.0 | . | -6.5 | 02 | 01 | | | 0.34 | . | 2 |
| 16 | 18 | 42.8 | 86.9 | 35 | 10 | 98 | | | . | 6 | 6 | 0 | 3 | X | 01.2 | 01.4 | 02.3 | . | -7.0 | | | | | 0.16 | . | 2 |
| 17 | 07 | 42.8 | 86.2 | 00 | 00 | 96 | 50 | 5 | . | 9 | 9 | X | X | X | 02.6 | 02.7 | 02.6 | . | -3.7 | 00 | 00 | | | 0.03 | . | 2 |
| 17 | 08 | 42.8 | 86.3 | 00 | 00 | 96 | 52 | 5 | . | 9 | 9 | X | X | X | 01.9 | 01.9 | 01.5 | . | -4.4 | 00 | 00 | | | 0.04 | . | 2 |
| 17 | 10 | 42.8 | 86.4 | 33 | 14 | 96 | 83 | 5 | . | 9 | 9 | X | X | X | 01.2 | 01.2 | 01.1 | . | -5.0 | 36 | 01 | | | 0.05 | . | 2 |
| 17 | 13 | 42.9 | 86.4 | 02 | 14 | 97 | 71 | 7 | . | 6 | | | | | 01.5 | 01.6 | 01.8 | . | -4.6 | 36 | 02 | | | 0.63 | . | 2 |
| 19 | 19 | 43.7 | 86.6 | 20 | 10 | 98 | | | . | 7 | 0 | 0 | 0 | 8 | 03.6 | 03.2 | 01.7 | . | -4.6 | 20 | 01 | | | 0.02 | . | 2 |
| 20 | 01 | 44.5 | 86.2 | | | | | | . | | | | | | 03.1 | 03.0 | 01.8 | . | -5.7 | | | | | 0.00 | . | 2 |
| 20 | 07 | 44.6 | 86.3 | 05 | 08 | 98 | | | . | 0 | | | | | 02.1 | 02.1 | 01.4 | . | -5.1 | 00 | 00 | | | 0.07 | . | 2 |
| 20 | 09 | 44.6 | 86.3 | 03 | 13 | 98 | | | . | 1 | 0 | 0 | 0 | 1 | 01.8 | 01.8 | 01.9 | . | -5.0 | 02 | 01 | | | . | . | 2 |
| 20 | 13 | 44.5 | 86.6 | | | 99 | | | . | 1 | 0 | | 0 | 1 | 01.5 | 01.6 | 01.8 | . | -6.8 | 02 | 02 | | | 1.17 | . | 2 |
| 21 | 07 | 44.6 | 86.3 | 23 | 08 | 96 | 10 | | . | 9 | 9 | X | X | X | 02.6 | 02.5 | 01.7 | . | -4.1 | 00 | 00 | | | 0.02 | . | 2 |
| 21 | 09 | 44.5 | 86.6 | 00 | 00 | 96 | 05 | 4 | . | 9 | 9 | X | X | X | 02.8 | 02.7 | 02.0 | . | -3.5 | 00 | 00 | | | 0.11 | | 2 |
| 21 | 11 | 44.5 | 86.9 | 01 | 04 | 95 | 45 | 4 | . | 9 | 9 | X | X | X | 02.8 | 02.5 | 02.0 | . | -2.3 | 00 | 00 | | | 0.63 | . | 2 |
| 21 | 13 | 44.4 | 87.1 | 32 | 12 | 96 | 05 | 4 | . | 9 | 9 | X | X | X | 02.5 | 02.4 | 01.9 | . | -3.3 | 00 | 00 | | | 1.60 | . | 2 |
| 21 | 15 | 44.4 | 87.1 | 07 | 06 | 97 | | | . | 1 | 0 | 0 | 0 | 1 | 02.8 | 02.6 | 01.6 | . | -2.9 | 00 | 00 | | | . | . | 2 |
| 21 | 18 | 44.4 | 87.4 | 30 | 08 | 96 | 05 | 5 | . | 8 | 8 | 3 | X | X | 03.4 | 03.4 | 03.1 | . | -3.7 | 00 | 00 | | | 0.06 | . | 2 |
| 22 | 07 | 44.4 | 87.4 | 15 | 04 | 98 | | | . | 1 | 0 | 0 | 0 | 1 | 02.9 | 03.0 | 01.6 | . | -6.9 | 00 | 00 | | | 0.23 | . | 2 |
| 23 | 07 | 43.7 | 87.6 | | | 97 | 05 | | . | 8 | 8 | 5 | X | X | 02.3 | 02.3 | 02.8 | . | -5.0 | 02 | 02 | | | 0.08 | . | 2 |
| 23 | 10 | 43.6 | 87.5 | | | 97 | 05 | | . | 8 | | | | | 02.0 | 02.2 | 01.4 | . | -4.1 | 02 | 02 | | | . | . | 2 |
| 23 | 13 | 43.7 | 87.6 | | | 97 | 05 | | . | 8 | | | | | 02.2 | 02.2 | 03.6 | . | -3.7 | 02 | 04 | | | 0.54 | . | 2 |
| 27 | 07 | 43.7 | 87.4 | | | 97 | 05 | | . | 0 | | | | | 03.3 | 02.7 | 01.5 | . | -5.1 | 00 | 00 | | | 0.02 | . | 2 |
| 27 | 08 | 43.8 | 87.0 | | | 96 | 05 | | . | 1 | 0 | 0 | 0 | 1 | 03.4 | 03.3 | 01.6 | . | -4.4 | 00 | 00 | | | 0.28 | . | 2 |
| 27 | 13 | 43.9 | 86.8 | | | 98 | | | . | 0 | | | | | 02.1 | 02.1 | 01.6 | . | -4.9 | 36 | 01 | | | 1.12 | . | 2 |
| 27 | 15 | 43.9 | 86.6 | | | 98 | | | . | 5 | | | | | 02.5 | 02.5 | 01.2 | . | -4.8 | 36 | 01 | | | 1.09 | . | 2 |
| 28 | 08 | 43.9 | 86.5 | | | 99 | | | . | 0 | | | | | 00.7 | 00.9 | 02.0 | . | -6.4 | 36 | 01 | | | 0.59 | . | 2 |
| 28 | 13 | 43.1 | 86.3 | | | | | | . | 0 | | | | | 01.9 | 02.1 | 03.6 | . | -4.8 | | | | | 1.30 | . | 2 |
| 29 | 13 | 42.8 | 86.4 | 21 | 11 | 98 | | | . | 0 | | | | | 05.1 | 04.8 | 02.2 | . | 04.6 | 25 | 01 | | | 1.30 | . | 2 |
| 29 | 14 | 42.8 | 86.4 | 22 | 19 | 97 | | | . | 0 | | | | | 05.1 | 04.7 | 02.0 | . | 04.2 | 25 | 01 | | | 0.66 | . | 2 |
| 29 | 18 | 42.8 | 86.3 | 19 | 12 | 97 | | | . | 0 | | | | | 06.3 | 06.1 | 03.3 | . | 05.2 | 20 | 01 | | | 0.20 | . | 2 |

MAY 1965

| TIMES | | LOCATIONS | | WINDS | | WEATHER | | | PRESSR | OKT | CLOUD | | | | TEMPERATURES (DEGREES C) | | | | | WAVES | | SWELL | | RADIATION | | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DY | HR | LATD | LONG | DD | FF | VV | WW | W | PPPPPP | N | A | L | M | H | AIRM | AIRB | WATI | WATS | TOPT | DD | HH | DD | HH | SOLR | NETR | V |
| 01 | 07 | 42.8 | 86.2 | 34 | 10 | 98 | | | . | 8 | 8 | 6 | X | X | 11.1 | 10.7 | 05.3 | . | 08.5 | 00 | 00 | | | 0.00 | . | 2 |
| 01 | 10 | 42.8 | 86.6 | | | 97 | | | . | 7 | 0 | 0 | 0 | 9 | 06.7 | 05.6 | 02.0 | . | 06.0 | 00 | 00 | | | . | . | 2 |
| 01 | 13 | 42.8 | 86.9 | | | 97 | | | . | 6 | 6 | 0 | 5 | 0 | 06.5 | 05.4 | 02.2 | . | 05.9 | 00 | 00 | | | . | . | 2 |
| 01 | 17 | 42.7 | 87.4 | 31 | 09 | 99 | | | . | 7 | 7 | 8 | 3 | 0 | 06.4 | 04.5 | 02.0 | . | 05.2 | 00 | 00 | 15 | 01 | 0.20 | . | 2 |
| 02 | 07 | 42.7 | 87.6 | | | 98 | | | . | 3 | 0 | 0 | 0 | 1 | 05.6 | 04.6 | 01.9 | . | 05.5 | 00 | 00 | 02 | 01 | 0.20 | . | 2 |
| 02 | 12 | 42.3 | 87.5 | 16 | 14 | 98 | | | . | 6 | 0 | 0 | 0 | 9 | 15.0 | 12.4 | 02.0 | . | 08.8 | 00 | 00 | | | 1.15 | . | 2 |
| 03 | 07 | 42.3 | 87.7 | 20 | 18 | 98 | | | . | 6 | 0 | 0 | 0 | 5 | 15.0 | 15.0 | 04.1 | . | 10.0 | 18 | 01 | | | 0.20 | . | 2 |
| 03 | 09 | 42.3 | 87.3 | 21 | 17 | 98 | | | . | 7 | 0 | 0 | 0 | 5 | 09.7 | 08.1 | 02.3 | . | 07.0 | 20 | 02 | | | 0.65 | . | 2 |
| 03 | 13 | 42.3 | 87.0 | 16 | 12 | 98 | | | . | | 0 | 0 | 0 | 1 | 09.1 | 07.5 | 02.3 | . | 07.5 | 20 | 01 | | | 1.03 | . | 2 |
| 03 | 16 | 42.4 | 86.5 | | | | | | . | 6 | 6 | 2 | 0 | 0 | 13.5 | 10.1 | 02.6 | . | 08.4 | 00 | 00 | | | 0.43 | . | 2 |
| 03 | 17 | 42.4 | 86.3 | 16 | 08 | 98 | | | . | 1 | 1 | 0 | 0 | 1 | 15.0 | 09.8 | 03.8 | . | . | 00 | 00 | | | 0.44 | . | 2 |
| 04 | 06 | 42.1 | 86.5 | 22 | 10 | 98 | | | . | 7 | 7 | 0 | 1 | X | 07.6 | 07.7 | 07.0 | . | . | | | 29 | 01 | 0.02 | . | 2 |
| 04 | 07 | 42.1 | 86.6 | 26 | 08 | 98 | | | . | 8 | 8 | 5 | X | X | 04.3 | 04.0 | 02.9 | . | . | | | 29 | 01 | 0.03 | . | 2 |
| 04 | 08 | 42.0 | 86.7 | 18 | 04 | 98 | | | . | 7 | 8 | 2 | X | X | 03.3 | 03.8 | 02.1 | . | . | | | 29 | 01 | 0.11 | . | 2 |
| 04 | 13 | 42.0 | 87.1 | 04 | 04 | 97 | | | . | 7 | 7 | 3 | 5 | X | 03.3 | 03.3 | 02.4 | . | . | | | 29 | 02 | 0.21 | . | 2 |
| 04 | 14 | 41.9 | 87.3 | 04 | 04 | 97 | | | . | 7 | 0 | 0 | 0 | 5 | 04.6 | 05.4 | 02.8 | . | . | | | 29 | 01 | 1.02 | . | 2 |
| 04 | 16 | 41.8 | 87.4 | 14 | 13 | 98 | 05 | | . | 1 | 0 | 0 | 0 | 1 | 05.4 | 05.5 | 06.9 | . | . | 15 | 01 | | | 0.20 | . | 2 |
| 05 | 13 | 41.9 | 87.5 | 07 | 04 | 90 | 45 | | . | 9 | 9 | X | X | X | 09.2 | 09.3 | 10.1 | . | . | | | 02 | 00 | 0.70 | . | 2 |
| 06 | 07 | 41.8 | 87.4 | 19 | 12 | 96 | 05 | 4 | . | 9 | 9 | X | X | X | 17.5 | 16.1 | 08.0 | . | . | 19 | 00 | | | 0.15 | . | 2 |
| 06 | 13 | 41.8 | 87.0 | 15 | 05 | 90 | 45 | 4 | . | 9 | 9 | X | X | X | 12.5 | 09.1 | 03.1 | . | . | 22 | 00 | | | 0.00 | . | 2 |
| 07 | 07 | 42.4 | 86.2 | 18 | 12 | 97 | 10 | | . | 0 | 0 | 0 | 0 | 0 | 17.5 | 13.0 | 07.2 | . | . | 18 | 00 | | | 0.20 | . | 2 |
| 08 | 13 | 43.0 | 86.2 | 18 | 08 | 98 | | | . | 1 | 0 | 0 | 0 | 1 | 12.5 | 12.5 | 08.4 | . | . | | | 20 | 02 | 1.15 | . | 2 |
| 08 | 19 | 44.0 | 86.5 | 19 | 09 | 98 | | | . | 3 | 3 | 1 | 0 | 0 | 09.0 | 08.4 | 04.0 | . | . | | | 20 | 02 | 0.11 | . | 2 |
| 09 | 07 | 44.6 | 86.3 | 00 | 00 | 90 | 45 | | . | 9 | 9 | X | X | X | 15.6 | 14.0 | 02.4 | . | . | | | 20 | 00 | 0.00 | . | 2 |
| 09 | 12 | 44.5 | 86.6 | 20 | 12 | 90 | 64 | 8 | . | 9 | 9 | X | X | X | 07.2 | 06.7 | 02.4 | . | . | 22 | 02 | | | 0.59 | . | 2 |
| 09 | 13 | 44.5 | 86.7 | 19 | 11 | 90 | 64 | 8 | . | 9 | 9 | X | X | X | 08.4 | 06.6 | 02.4 | . | . | 22 | 02 | | | 0.47 | . | 2 |
| 09 | 16 | 44.4 | 87.1 | 18 | 15 | 93 | 10 | 4 | . | 3 | 0 | 0 | 0 | 1 | 05.2 | 04.8 | 02.2 | . | . | 22 | 02 | | | 1.04 | . | 2 |
| 09 | 19 | 44.1 | 87.4 | 17 | 10 | 96 | | 4 | . | 1 | 0 | 0 | 0 | 1 | 07.3 | 06.7 | 04.4 | . | . | 17 | 01 | | | 0.07 | . | 2 |
| 10 | 07 | 43.6 | 87.5 | 22 | 12 | 97 | | | . | 4 | 4 | 2 | 0 | 1 | 12.5 | 08.5 | 02.1 | . | . | 22 | 01 | | | 0.28 | . | 2 |
| 10 | 11 | 43.8 | 87.0 | 24 | 06 | 99 | | | . | 1 | 0 | 0 | 0 | 1 | 06.1 | 05.0 | 02.2 | . | . | 18 | 00 | | | 1.00 | . | 2 |
| 10 | 13 | 43.8 | 86.8 | 22 | 10 | 99 | | | . | 0 | 0 | 0 | 0 | 0 | 05.6 | 04.5 | 02.1 | . | . | 15 | 00 | | | 1.26 | . | 2 |
| 10 | 14 | 43.9 | 86.6 | 25 | 09 | 99 | | | . | 1 | 0 | 0 | 0 | 1 | 05.8 | 05.0 | 02.4 | . | . | 15 | 00 | | | 1.13 | . | 2 |
| 10 | 19 | 43.3 | 86.4 | 30 | 10 | 99 | | | . | 4 | 4 | 0 | 3 | 0 | 06.7 | 06.8 | 07.2 | . | . | 15 | 00 | | | . | . | 2 |
| 15 | 07 | 42.0 | 86.5 | 16 | 12 | 98 | | 6 | . | 8 | 8 | 0 | 3 | X | 17.3 | 20.1 | 10.5 | . | . | 15 | 00 | | | 0.11 | . | 1 |
| 15 | 12 | 41.9 | 87.1 | 18 | 18 | 98 | | 6 | . | 8 | 8 | 0 | 3 | X | 17.1 | 15.8 | 11.4 | . | 12.8 | 18 | 01 | | | . | . | 1 |
| 16 | 13 | 42.6 | 87.7 | 23 | 08 | 99 | | | 1006.9 | 8 | 8 | 5 | X | X | 17.6 | . | 06.4 | . | . | 22 | 01 | | | 0.25 | 0.21 | 1 |
| 17 | 13 | 42.8 | 86.9 | 29 | 04 | 95 | 10 | 4 | 1018.3 | 8 | 8 | 6 | X | X | 05.7 | . | 03.4 | . | 05.5 | 00 | 00 | | | 0.46 | 0.41 | 1 |
| 17 | 15 | 42.8 | 86.4 | 00 | 00 | 95 | 10 | 4 | 1017.2 | 8 | 8 | 6 | X | X | 05.7 | . | 04.3 | . | 05.2 | 00 | 00 | | | 0.55 | 0.49 | 1 |
| 18 | 07 | 42.4 | 86.4 | 15 | 12 | 98 | | | 1013.8 | 0 | 0 | 0 | 0 | 0 | 09.4 | . | 03.8 | . | 08.5 | 15 | 01 | | | 0.25 | 0.24 | 1 |
| 18 | 08 | 42.4 | 86.5 | 15 | 15 | 98 | | | 1013.3 | 0 | 0 | 0 | 0 | 0 | 09.6 | . | 03.9 | . | 08.6 | 15 | 01 | | | 0.51 | 0.54 | 1 |
| 18 | 11 | 42.3 | 87.0 | 16 | 11 | 96 | 10 | 4 | 1012.2 | 7 | 7 | 4 | 3 | 0 | 11.1 | . | 03.8 | . | 10.6 | 00 | 00 | 15 | 00 | 1.14 | 1.10 | 1 |
| 18 | 13 | 42.3 | 87.4 | 13 | 05 | 96 | 10 | 4 | 1011.4 | 1 | 0 | 0 | 0 | 1 | 11.0 | . | 03.2 | . | 10.4 | 00 | 00 | | | 1.22 | 1.16 | 1 |
| 18 | 14 | 42.3 | 87.5 | 17 | 06 | 95 | 10 | 4 | 1011.2 | 2 | 2 | 3 | 0 | 1 | 12.3 | . | 03.2 | . | 11.4 | 00 | 00 | | | 1.21 | 1.19 | 1 |
| 18 | 17 | 41.8 | 87.4 | 32 | 16 | 97 | 95 | 8 | 1012.2 | 8 | 8 | 3 | X | X | 14.9 | . | 11.0 | . | 14.8 | 32 | 01 | | | 0.01 | 0.02 | 1 |
| 19 | 07 | 41.9 | 87.4 | 33 | 16 | 99 | | | 1020.3 | 5 | 0 | 0 | 0 | 5 | 11.4 | . | 09.7 | . | 07.8 | 32 | 01 | | | 0.28 | 0.02 | 1 |
| 19 | 09 | 42.0 | 87.1 | 34 | 11 | 99 | | | 1021.8 | 3 | 0 | 0 | 0 | 5 | 06.4 | . | 03.5 | . | 05.2 | 32 | 00 | | | 0.95 | 0.79 | 1 |
| 19 | 11 | 42.0 | 86.7 | 36 | 12 | 99 | | | 1022.8 | 5 | 0 | 0 | 0 | 5 | 05.7 | . | 03.5 | . | 05.0 | 36 | 00 | | | 0.94 | 0.78 | 1 |
| 19 | 13 | 42.2 | 86.6 | 01 | 10 | 98 | | | 1022.8 | 6 | 0 | 0 | 0 | 5 | 06.4 | . | 04.1 | . | 04.6 | 34 | 00 | | | 1.09 | 0.93 | 1 |
| 19 | 19 | 42.9 | 86.3 | 29 | 11 | 99 | | | 1022.2 | 2 | 0 | 0 | 0 | 1 | 12.6 | . | 03.6 | . | 02.4 | 27 | 00 | | | 0.15 | 0.05 | 1 |
| 24 | 07 | 43.1 | 86.3 | 15 | 11 | 98 | | | 1022.3 | 8 | 8 | 5 | X | X | 14.8 | 14.5 | 08.8 | . | 08.4 | 09 | 01 | | | . | . | 1 |
| 24 | 13 | 44.1 | 86.5 | 11 | 02 | 98 | | | 1020.8 | 3 | 3 | 5 | 0 | 0 | 17.1 | 11.1 | 02.8 | . | 09.1 | 00 | 00 | | | . | . | 1 |
| 24 | 17 | 44.6 | 86.3 | 36 | 05 | 98 | | | 1018.6 | 1 | 0 | 0 | 0 | 1 | 12.3 | 08.7 | 03.1 | . | 06.4 | 36 | 00 | | | . | . | 1 |
| 24 | 18 | 44.6 | 86.3 | 36 | 05 | 98 | | | 1017.8 | 3 | 0 | 0 | 0 | 1 | 17.8 | 14.7 | 08.2 | . | 09.5 | 36 | 00 | | | . | . | 1 |
| 25 | 07 | 44.5 | 86.4 | 19 | 12 | 92 | 45 | | 1013.9 | 9 | 9 | X | X | X | 08.8 | 07.4 | 02.6 | . | 06.8 | 18 | 01 | | | . | . | 1 |
| 25 | 08 | 44.5 | 86.6 | 19 | 13 | 92 | 45 | 4 | 1012.8 | 7 | 7 | 5 | X | X | 06.5 | 05.7 | 02.5 | . | 05.0 | 18 | 01 | | | . | . | 1 |
| 25 | 12 | 44.5 | 86.9 | 19 | 11 | 92 | 45 | 4 | 1011.4 | 9 | 9 | X | X | X | 06.5 | 05.2 | 02.5 | . | 04.9 | 18 | 02 | | | . | . | 1 |
| 25 | 14 | 44.4 | 87.1 | 18 | 10 | 92 | 45 | 4 | 1010.4 | 9 | 9 | X | X | X | 06.1 | 05.6 | 02.5 | . | 04.5 | 18 | 01 | | | . | . | 1 |
| 25 | 15 | 44.4 | 87.4 | 17 | 13 | 95 | 10 | 4 | 1009.8 | 3 | 0 | 0 | 0 | 5 | 11.3 | 10.9 | 07.5 | . | 10.0 | 19 | 01 | | | . | . | 1 |
| 26 | 08 | 43.9 | 87.6 | 18 | 10 | 92 | 45 | 4 | 1004.2 | 9 | 9 | X | X | X | 06.6 | 06.1 | 05.4 | . | 04.5 | 18 | 01 | | | . | . | 1 |
| 26 | 09 | 43.7 | 87.6 | 20 | 10 | 92 | 45 | 4 | 1003.8 | 9 | 9 | X | X | X | 06.6 | 06.1 | 03.4 | . | 04.9 | 18 | 01 | | | . | . | 1 |
| 26 | 11 | 43.7 | 87.5 | 15 | 13 | 90 | 45 | 4 | 1001.0 | 8 | 8 | 5 | 6 | 7 | 09.1 | 07.6 | 02.6 | . | 07.0 | 16 | 02 | | | . | . | 1 |
| 26 | 13 | 43.7 | 87.4 | 18 | 18 | 98 | | | 1001.3 | 3 | 0 | 0 | 0 | 7 | 09.1 | 07.8 | 03.1 | . | 05.9 | 18 | 02 | | | . | . | 1 |
| 27 | 07 | 43.7 | 87.5 | 24 | 17 | 99 | | | 1003.2 | 7 | 7 | 5 | 0 | 0 | 08.8 | 08.0 | 03.4 | . | 01.9 | 25 | 01 | 20 | 02 | . | . | 1 |
| 27 | 09 | 43.8 | 87.0 | 24 | 13 | 99 | | | 1004.0 | 8 | 8 | 5 | X | X | 06.3 | 05.8 | 02.8 | . | 00.5 | 25 | 01 | | | . | . | 1 |
| 27 | 11 | 43.9 | 86.8 | 24 | 14 | 99 | | | 1005.0 | 8 | 8 | 5 | X | X | 05.5 | 05.0 | 02.8 | . | 00.6 | 25 | 01 | 22 | 01 | . | . | 1 |
| 27 | 14 | 43.9 | 86.5 | 22 | 18 | 99 | | | 1006.8 | 8 | 8 | 5 | X | X | 06.1 | 06.1 | 06.3 | . | 01.4 | 22 | 02 | | | . | . | 1 |
| 28 | 13 | 43.8 | 86.5 | 28 | 10 | 98 | | | 1013.0 | 8 | 8 | 5 | X | X | 05.3 | 05.3 | 11.4 | . | -0.7 | 27 | 02 | 23 | 02 | . | . | 1 |
| 28 | 17 | 43.2 | 86.5 | 24 | 12 | 99 | | | 1004.8 | 8 | 8 | 5 | X | X | 05.0 | 04.8 | 03.9 | . | -0.7 | 25 | 01 | | | . | . | 1 |
| 28 | 19 | 43.1 | 86.3 | 25 | 11 | 99 | | | 1005.2 | 8 | 8 | 5 | X | X | 06.3 | 06.4 | 10.8 | . | 00.7 | 25 | 01 | | | . | . | 1 |

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TIMES LOCATIONS WINDS WEATHER PRESSR CKT CLOUD TEMPERATURES (DEGREES C) WAVES SWELL RADIATION V
DY HR LATD LONG DD FF VV WW W PPPPPP N A L M H AIRM AIRB WATI WATS TDPT DD HH DD HH SOLR NETR V

                                      JUNE 1965

01 08 42.8 86.2 20 04 97 05   1014.2 7 7 0 7 7 14.3 14.3 13.1    . 10.7 15 00          .    . 1
01 12 42.8 86.6 14 07 97 05   1013.6 6 0 0 0 7 14.2 09.8 03.5    . 09.8 15 00          .    . 1
01 13 42.8 86.9 14 07 97 05   1013.2 6 0 0 0 7 06.8 05.5 03.3    . 05.5 15 00          .    . 1
01 17 42.7 87.4 11 06 96 80   1012.2 8 8 6 X X 12.6 09.1 04.8    . 07.2 15 00          .    . 1
02 07 42.7 87.5 35 16 91 45   1012.6 9 9 X X X 07.0 06.8 07.0    . 04.2 36 01          .    . 1
02 10 42.3 87.6 35 18 94 45 4 1013.1 9 9 X X X 07.3 07.0 05.2    . 04.5 36 02          .    . 1
02 12 42.3 87.7 35 17 94 45 4 1013.9 9 9 X X X 09.6 09.5 08.7    . 06.4 36 03          .    . 1
03 08 42.3 87.5 07 03 98      1019.5 7 7 0 2 8 06.1 05.6 03.8    . 01.6 04 03 04 01    .    . 1
03 09 42.3 87.3 06 06 98      1019.9 7 0 0 0 8 06.0 06.0 03.8    . 02.0 09 00 04 01    .    . 1
03 11 42.3 87.0 06 06 98      1019.5 8 0 0 0 8 07.3 06.4 03.6    . 03.0 04 00          .    . 1
03 13 42.3 86.5 06 06 98      1018.6 6 0 0 0 8 11.6 09.8 06.3    . 05.8 04 00          .    . 1
03 14 42.4 86.5 09 05 98      1018.3 4 0 0 0 8 13.4 12.7 07.5    . 07.5 04 00 04 00    .    . 1
03 15 42.4 86.4 12 06 98      1018.6 2 0 0 0 8 18.1 17.1 10.9    . 07.4 15 00          .    . 1
03 16 42.4 86.3 12 11 98      1018.2 1 0 0 0 1 18.1 16.7 11.8    . 06.4 15 00          .    . 1
03 18 42.1 86.5 12 11 98      1017.7 2 0 0 0 1 18.6 18.0 13.8    . 05.5 10 00          .    . 1
04 07 42.1 86.6 12 13 98      1021.3 1 0 0 0 1 12.6 13.0 12.6    . 04.7 10 00          .    . 1
04 07 42.0 86.7 12 13 98      1020.8 1 0 0 0 1 13.0 12.5 09.6    . 05.3 10 00          .    . 1
04 10 42.0 87.1 11 10 98      1020.2 1 0 0 0 1 10.1 08.8 06.3    . 05.6 10 00          .    . 1
04 12 41.9 87.3 08 06 98      1019.2 1 0 0 0 1 11.7 10.3 07.5    . 05.5 09 00          .    . 1
04 13 41.8 87.4 08 07 98      1018.2 1 0 0 0 8 13.4 13.3 11.3    . 06.4 09 00 09 00    .    . 1
05 07 41.9 87.5 14 08 97 05   1015.7 7 7 5 2 0 12.5 12.0 10.5    . 07.9 12 00          .    . 1
05 13 42.7 86.6 16 10 95 10 8 1015.2 8 8 5 X X 13.8 10.3 04.8    . 09.9 15 00          .    . 1
09 07 42.9 86.3 00 00 98      1016.5 3 3 1 4 9 12.0 08.3 06.7 06.3 06.9 00 00          .    . 1
09 13 42.6 86.9 00 00 97      1016.2 0 0 0 0 0 13.8 09.1 03.7    . 06.0 00 00          .    . 1
09 19 42.7 87.7 20 05 98      1013.8 7 0 0 0 2 15.3 14.7 11.9 12.5 05.6 20 00          .    . 1
10 13 42.5 87.2 33 08 99      1020.2 2 0 0 0 1 08.2 06.7 03.8 03.8 03.3 36 00          .    . 1
11 07 42.3 87.6 06 06 98      1020.2 0 0 0 0 0 11.5 11.6 13.2 13.4 04.0 04 00          .    . 1
11 13 42.7 86.6 30 04 98      1018.6 3 0 0 0 1 13.5 13.0 08.1 13.5 06.4 00 00          .    . 1
15 13 43.0 86.8 36 11 97 05        . 1 1 1 0 0 08.4 08.0 05.9    . 05.8 36 00       1.26    . 2
21 07 43.1 86.3 32 06 98      1011.3 0 0 0 0 0 11.4 10.5 09.1 09.5 04.8 33 00          .    . 1
21 13 44.1 86.5 20 12 99      1012.6 0 0 0 0 0 11.3 10.0 04.8 05.2 05.0 18 00          .    . 1
21 17 44.6 86.3 20 10 99      1012.1 0 0 0 0 0 10.4 10.3 08.0 08.7 03.0 22 01          .    . 1
22 06 44.5 86.4 18 12 98  .   1014.7 3 0 0 0 1 13.8 12.6 08.2 09.1 04.2 18 01          .    . 1
22 13 44.5 86.9 19 13 97 10 8 1013.5 8 8 0 2 7 08.7 07.1 03.6 03.8 06.5 20 02          .    . 1
22 16 44.4 87.4 18 08 96 10 4 1011.7 8 8 2 2 7 14.4 12.7 10.3 11.2 08.5 20 01          .    . 1
23 07 44.3 87.3 21 11 96 10   1009.5 7 7 0 5 7 13.0 12.5 10.6 11.4 07.2       15 02    .    . 1
23 13 43.7 86.6 26 10 91 45 4 1012.2 2 2 0 5 0 09.9 08.9 05.5 05.8 06.5       20 01    .    . 1
23 16 43.9 86.6 04 06 98    4 1014.2 4 4 1 0 0 11.7 09.9 06.4 06.4 05.4 04 01 21 01    .    . 1
23 17 43.9 86.5 10 16 98      1014.0 0 0 0 0 0 17.3 16.0 10.1 10.3 05.7 04 01          .    . 1
24 07 43.9 86.6 35 06 99      1020.2 0 0 0 0 0 09.6 08.7 07.7 07.8 01.9 36 00          .    . 1
24 08 43.9 86.8 35 06 99      1021.2 0 0 0 0 0 08.7 08.4 06.7 07.0 02.1 36 00          .    . 1
24 11 43.8 87.0 35 02 99      1022.1 0 0 0 0 0 13.1 11.1 06.6 10.9 03.6 00 00          .    . 1
24 13 43.6 87.5 13 06 99      1022.2 0 0 0 0 0 14.8 13.7 13.0 14.0 05.7 00 00          .    . 1
25 07 43.2 87.7 35 08 99      1024.5 0 0 0 0 0 11.2 11.2 11.5 11.7 04.0 04 00          .    . 1
25 13 43.2 86.7 30 08 99      1025.0 0 0 0 0 0 14.2 13.3 12.6 13.3 06.5 00 00          .    . 1
25 15 43.1 86.3 33 12 99      1024.2 1 0 0 0 1 15.7 15.6 14.8 14.4 06.4 33 00          .    . 1
28 07 43.0 86.2 20 18 97 05   1018.8 6 6 0 3 1 18.0 17.7 15.8 15.8 10.1 22 02          .    . 1
28 09 42.8 86.2 19 15 97 05   1018.6 5 5 0 3 1 18.0 17.8 14.0 14.8 10.5 22 02          .    . 1
28 11 42.8 86.4 21 17 97 05   1018.8 5 5 0 3 4 19.7 17.8 13.8 14.3 11.7 20 02          .    . 1
29 07 42.9 86.3 31 10 98      1018.6 5 0 0 0 8 14.4 14.8 13.4 13.5 06.2 32 00          .    . 1
29 09 42.8 86.6 31 06 97      1019.2 7 0 0 0 8 14.2 14.8 12.9 12.9 06.7 30 00          .    . 1
29 10 42.8 86.9 33 03 97      1019.6 7 7 0 3 9 14.1 13.6 08.8 08.8 06.9 00 00          .    . 1
29 13 42.7 87.4 09 06 97      1019.2 8 8 0 6 0 14.8 14.5 14.2 14.8 05.7 00 00          .    . 1
29 15 42.7 87.5 09 08 97      1018.6 8 8 0 6 0 15.6 15.6 17.1 16.0 06.8 09 00          .    . 1
29 18 42.3 87.6 12 06 98      1018.6 8 8 5 6 0 16.8 16.9 17.3 17.8 08.8 12 00          .    . 1
29 19 42.3 87.7 09 04 98      1018.8 8 8 5 6 0 16.8 16.8 17.3 17.1 09.9 09 00          .    . 1
30 07 42.2 87.6 01 17 99      1022.2 3 3 0 3 7 12.7 12.9 14.3 15.1 03.0 03 03          .    . 1
30 10 41.9 87.3 02 17 99      1023.8 3 3 0 0 7 12.8 12.7 17.2 17.2 05.2 03 04          .    . 1
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| TIMES | | LOCATIONS | | WINDS | | WEATHER | | | PRESSR | CK1 | CLOUD | | | | TEMPERATURES (DEGREES C) | | | | | WAVES | | SWELL | | RADIATION | | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DY | HR | LATD | LONG | DD | FF | VV | WW | W | PPPPPP | N | A | L | M | H | AIRM | AIRB | WATI | WATS | TOPT | DD | HH | DD | HH | SOLR | NETR | V |

JULY 1965

| DY | HR | LATD | LONG | DD | FF | VV | WW | W | PPPPPP | N | A | L | M | H | AIRM | AIRB | WATI | WATS | TOPT | DD | HH | DD | HH | SOLR | NETR | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 07 | 41.8 | 87.4 | 02 | 06 | 98 | | | 1023.9 | 8 | 0 | 0 | 0 | 7 | 16.7 | 16.6 | 12.5 | 12.5 | 08.0 | 04 | 00 | | | . | . | 1 |
| 01 | 09 | 42.0 | 87.1 | 16 | 07 | 98 | | | 1024.2 | 6 | 0 | 0 | 0 | 2 | 16.8 | 17.1 | 15.1 | 15.1 | 07.8 | 16 | 00 | | | . | . | 1 |
| 01 | 13 | 42.3 | 87.4 | 11 | 09 | 97 | | | 1021.9 | 8 | 0 | 0 | 0 | 2 | 15.0 | 16.0 | 12.7 | 13.4 | 07.7 | 00 | 00 | | | . | . | 1 |
| 01 | 15 | 42.3 | 87.0 | 12 | 08 | 97 | | | 1021.2 | 8 | 0 | 0 | 0 | 2 | 19.0 | 17.0 | 13.4 | 14.2 | 07.9 | 00 | 00 | | | . | . | 1 |
| 02 | 07 | 42.1 | 86.6 | 19 | 14 | 97 | C5 | | 1010.2 | 8 | 8 | 0 | 5 | 0 | 19.4 | 19.1 | 16.9 | 17.3 | 11.2 | 22 | 02 | | | . | . | 1 |
| 02 | 08 | 42.0 | 86.7 | 19 | 14 | 97 | 05 | 8 | 1010.2 | 8 | 8 | 0 | 5 | 7 | 19.1 | 18.8 | 16.9 | 16.9 | 11.3 | 20 | 02 | | | . | . | 1 |
| 02 | 11 | 42.4 | 86.5 | 19 | 17 | 97 | 05 | | 1010.2 | 8 | 8 | 0 | 5 | 0 | 18.8 | 18.8 | 17.0 | 17.0 | 11.7 | 20 | 02 | | | . | . | 1 |
| 02 | 13 | 42.5 | 86.3 | 21 | 13 | 96 | 10 | | 1009.5 | 8 | 8 | 0 | 5 | 0 | 19.0 | 19.0 | 15.1 | 16.2 | 11.4 | 20 | 02 | | | . | . | 1 |
| 06 | 13 | 43.2 | 87.1 | 12 | 10 | 98 | | | 1019.8 | 8 | 0 | 0 | 0 | 7 | 14.4 | 14.1 | 11.7 | 12.3 | 05.8 | 10 | 01 | | | . | . | 1 |
| 06 | 19 | 43.6 | 87.6 | 12 | 08 | 97 | | 8 | 1015.2 | 8 | 8 | 7 | X | X | 15.5 | 13.5 | 11.8 | 12.3 | 07.2 | 10 | 01 | | | . | . | 1 |
| 07 | 07 | 43.8 | 87.6 | 15 | 05 | 91 | 45 | | 1008.9 | 9 | 9 | X | X | X | 13.7 | 13.3 | 12.0 | 12.4 | . | 00 | 00 | | | . | . | 1 |
| 07 | 13 | 44.1 | 87.3 | 21 | 05 | 96 | 10 | 4 | 1009.1 | 5 | 5 | 5 | 0 | 0 | 16.0 | 15.2 | 13.5 | 14.1 | . | 20 | 00 | | | . | . | 1 |
| 08 | 07 | 44.4 | 87.3 | 34 | 05 | 97 | | | 1013.2 | 1 | 0 | 0 | 0 | 1 | 12.8 | 12.6 | 12.0 | 12.3 | . | 00 | 00 | | | . | . | 1 |
| 08 | 13 | 44.2 | 87.0 | 12 | 06 | 96 | | | 1013.2 | 5 | 5 | 5 | 1 | 0 | 15.9 | 15.0 | 13.9 | 13.7 | 07.2 | 14 | 00 | | | . | . | 1 |
| 08 | 19 | 44.1 | 86.7 | 16 | 11 | 98 | | | 1009.8 | 8 | 8 | 3 | 0 | 7 | 14.2 | 13.0 | 10.4 | 10.9 | 06.2 | 00 | 00 | | | . | . | 1 |
| 09 | 13 | 43.8 | 86.6 | 01 | 12 | 96 | 10 | 8 | 1008.0 | 8 | 8 | 6 | 2 | 0 | 12.8 | 12.4 | 11.2 | 11.5 | 08.2 | 36 | 01 | | | . | . | 1 |
| 09 | 19 | 43.1 | 86.3 | 35 | 14 | 99 | | | 1010.6 | 1 | 1 | 0 | 4 | 0 | 21.8 | 21.9 | 17.4 | 17.8 | 08.0 | 36 | 01 | | | . | . | 1 |
| 14 | 07 | 42.9 | 86.2 | 34 | 1[illegible] | 98 | | | 1013.8 | 8 | 8 | 0 | 5 | 1 | 19.1 | 19.2 | 18.5 | 18.7 | 09.7 | 30 | 01 | | | . | . | 1 |
| 14 | 09 | 42.8 | 86.4 | 32 | 07 | 98 | | | 1015.9 | 8 | 8 | 0 | 5 | 1 | 17.2 | 17.8 | 16.8 | 16.9 | 08.2 | 30 | 01 | | | . | . | 1 |
| 14 | 11 | 42.8 | 86.6 | 32 | 06 | 99 | | | 1016.0 | 6 | 6 | 1 | 2 | 1 | 17.5 | 17.5 | 18.4 | 18.8 | 07.7 | 30 | 01 | | | . | . | 1 |
| 14 | 13 | 42.8 | 86.9 | 35 | 03 | 99 | | | 1016.8 | 6 | 0 | 0 | 0 | 9 | 20.3 | 20.3 | 16.0 | 15.7 | 09.7 | 00 | 00 | | | . | . | 1 |
| 14 | 16 | 42.7 | 87.4 | 32 | 05 | 99 | | | 1015.0 | 3 | 3 | 1 | 0 | 1 | 21.6 | 21.7 | 19.9 | 20.5 | 09.8 | 20 | 00 | | | . | . | 1 |
| 14 | 17 | 42.7 | 87.5 | 17 | 07 | 99 | | | 1014.7 | 3 | 3 | 1 | 0 | 0 | 22.5 | 22.6 | 20.3 | 20.9 | 10.7 | 20 | 00 | | | . | . | 1 |
| 15 | 07 | 42.8 | 87.7 | 32 | 08 | 99 | | | 1017.7 | 0 | 0 | 0 | 0 | 0 | 17.7 | 17.4 | 17.2 | 17.4 | 05.7 | 30 | 01 | | | . | . | 1 |
| 15 | 13 | 43.3 | 87.7 | 16 | 04 | 99 | | | 1018.2 | 0 | 0 | 0 | 0 | 0 | 17.8 | 17.5 | 16.3 | 17.8 | 05.2 | 00 | 00 | | | . | . | 1 |
| 15 | 17 | 43.7 | 87.6 | 18 | 10 | 99 | | | 1015.2 | 1 | 1 | 1 | 0 | 0 | 18.1 | 18.5 | 16.5 | 16.7 | 06.4 | 18 | 01 | | | . | . | 1 |
| 16 | 07 | 43.7 | 87.5 | 20 | 16 | 99 | | | 1010.7 | 6 | 6 | 1 | 5 | 0 | 16.7 | 16.6 | 15.5 | 15.8 | 07.4 | 20 | 02 | | | . | . | 1 |
| 16 | 09 | 43.8 | 87.0 | 21 | 15 | 99 | | | 1018.2 | 3 | 3 | 0 | 2 | 7 | 17.0 | 16.9 | 15.1 | 15.4 | 08.0 | 20 | 02 | | | . | . | 1 |
| 16 | 12 | 43.9 | 86.8 | 22 | 10 | 98 | | | 1010.6 | 2 | 2 | 0 | 4 | 6 | 17.2 | 17.2 | 15.7 | 16.2 | 08.3 | 22 | 01 | | | . | . | 1 |
| 17 | 13 | 44.4 | 87.1 | 01 | 10 | 98 | | | 1015.3 | 5 | 5 | 2 | 5 | 0 | 15.7 | 15.5 | 15.0 | 15.3 | 06.8 | 02 | 01 | | | . | . | 1 |
| 17 | 16 | 44.4 | 87.4 | 03 | 12 | 96 | C5 | | 1016.4 | 6 | 6 | 2 | 3 | 0 | 14.3 | 14.3 | 11.4 | 11.9 | 05.8 | 34 | 00 | | | . | . | 1 |
| 18 | 07 | 44.4 | 87.2 | 33 | 06 | 97 | 05 | | 1017.9 | 8 | 8 | 0 | 3 | X | 14.5 | 14.5 | 14.3 | 14.5 | 05.7 | 04 | 00 | | | . | . | 1 |
| 18 | 08 | 44.5 | 86.9 | 06 | 04 | 97 | 05 | | 1018.1 | 8 | 8 | 0 | 3 | X | 15.6 | 15.5 | 15.1 | 15.3 | 05.7 | 00 | 00 | | | . | . | 1 |
| 18 | 11 | 44.5 | 86.6 | 02 | 07 | 98 | | 8 | 1019.2 | 6 | 6 | 0 | 3 | 0 | 15.7 | 15.7 | 14.5 | 14.9 | . | 00 | 00 | | | . | . | 1 |
| 18 | 13 | 44.5 | 86.5 | 02 | 07 | 99 | | | 1018.8 | 6 | 6 | 2 | 0 | 5 | 15.3 | 15.5 | 13.7 | 14.2 | . | 34 | 00 | | | . | . | 1 |
| 18 | 14 | 44.6 | 86.3 | 01 | 13 | 99 | | | 1019.1 | 1 | 1 | 1 | 0 | 0 | 16.2 | 16.3 | 15.2 | 16.2 | 12.6 | 02 | 01 | | | . | . | 1 |
| 19 | 07 | 44.5 | 86.2 | 01 | 03 | 98 | | | 1020.5 | 1 | 1 | 1 | 0 | 0 | 13.5 | 13.7 | 15.1 | 15.1 | 10.6 | 00 | 00 | | | . | . | 1 |
| 19 | 13 | 44.3 | 86.5 | 34 | 12 | 99 | | | 1023.1 | C | 0 | 0 | 0 | 0 | 14.9 | 14.9 | 14.3 | 14.3 | 12.5 | 34 | 00 | | | . | . | 1 |
| 20 | 08 | 43.8 | 86.5 | 12 | 14 | 99 | | | 1023.9 | 7 | 0 | 0 | 0 | 9 | 15.2 | 15.1 | 13.7 | 13.9 | 04.2 | 22 | 00 | | | . | . | 1 |
| 22 | 13 | 43.1 | 86.3 | 18 | 05 | 94 | 05 | | 1014.5 | 3 | 3 | 0 | 3 | 0 | 20.0 | 20.4 | 18.4 | 18.9 | 18.8 | 22 | 00 | | | . | . | 1 |
| 23 | 13 | 43.1 | 86.3 | 27 | 09 | 97 | 05 | | 1012.8 | 2 | 2 | 1 | 0 | 1 | 24.1 | 23.6 | 21.0 | 22.8 | 20.2 | 33 | 00 | | | . | . | 1 |

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TIMES LOCATIONS WINDS WEATHER PRESSR CKT CLOUD TEMPERATURES (DEGREES C) WAVES SWELL RADIATION V
DY HR LATD LONG DD FF VV WW W PPPPPP N A L M H AIRM AIRB WATI WATS TDPT DD HH DD HH SOLR NETR V

                                      AUGUST 1965

05 07 43.1 86.3 12 08 91 10   1017.4 2 0 0 0 1 14.1 11.9 11.4 11.5 13.8 15 00       0.00 0.17 1
05 13 43.6 86.9 20 04 96 10   1016.3 2 0 0 0 8 18.5 19.3 18.0 18.4 15.4 18 00       1.25 1.35 1
06 07 44.0 86.5 19 14 97      1013.2 3 0 0 0 8 20.4 19.9 17.6 17.8 15.0 18 01       0.00 0.15 1
06 13 44.2 86.7 19 19 97 05   1012.6 3 0 0 0 8 19.8 19.6 17.5 18.2 15.3 18 02       1.20 1.24 1
07 13 44.7 86.1 21 10 97 05   1008.7 8 8 6 X X 20.6 20.2 15.4 16.2 15.4 22 01       1.00 0.96 1
08 07 44.5 86.3 03 09 97 10 4 1007.5 8 8 6 0 8 18.3 17.3 15.9 16.7 15.0 04 00       0.05 0.03 1
08 13 44.1 86.5 13 04 98 10 4 1007.2 8 8 6 X X 18.5 18.5 16.4 16.6 14.9 07 00       0.35 0.35 1
08 19 43.1 86.3 00 00 98    8 1005.2 8 8 4 X X 20.1 19.1 16.1 17.3 15.0 00 00       0.00 0.00 1
10 07 43.1 86.3 36 15 98      1017.8 7 7 4 2 0 15.0 14.9 15.2 15.2 11.5 36 03       0.00    . 1
10 08 43.2 86.5 34 13 98      1019.4 5 5 2 0 0 13.7 13.4 12.3 12.2 10.4 34 03       0.00    . 1
11 07 43.0 85.3 15 04 98      1021.3 0 0 0 0 0 11.6 11.0 13.2 14.8 08.4 04 00       0.20    . 1
11 13 43.2 87.6 18 12 98      1020.3 1 0 0 0 1 19.6 19.8 19.1 19.6 13.9 15 01       1.22    . 1
11 19 43.6 87.5 19 14 97      1017.1 2 0 0 0 8 20.0 20.4 18.7 19.5 14.4 18 03       0.12    . 1
12 07 43.7 87.5 22 13 97 05   1016.6 4 4 2 3 0 18.8 18.9 17.4 17.5 14.3 20 01 18 02 0.00    . 1
12 09 43.8 87.0 22 19 97 05   1016.4 2 2 1 0 1 19.5 20.0 17.4 17.6 15.0 22 03       0.62    . 1
12 13 43.9 86.6 20 22 97 05   1013.5 6 6 0 3 8 19.0 18.8 16.8 17.6 13.6 22 04       0.70    . 1
12 14 43.9 86.5 20 20 97 05   1013.6 7 0 0 0 8 17.6 17.4 15.4 16.0 12.3 20 04       1.00    . 1
13 13 44.1 86.9 03 07 91 45 4 1016.3 9 9 X X X 16.9 16.9 17.2 17.4 12.9 32 00       0.57    . 1
13 16 44.4 87.1 10 03 97 10 4 1015.8 6 0 0 0 8 19.6 19.5 18.1 20.4 14.6 15 00       0.87    . 1
14 07 44.4 87.2 21 15 95 10 4 1013.8 0 0 0 0 0 19.3 19.4 18.0 18.0 15.0 22 01       0.00    . 1
14 09 44.5 85.9 23 16 96 10 4 1013.4 0 0 0 0 0 19.9 19.6 17.4 17.8 14.7 20 02       0.65    . 1
14 11 44.5 86.6 20 15 96 10 4 1013.8 0 0 0 0 0 20.0 19.7 17.3 17.7 14.8 22 02       1.00    . 1
14 13 44.5 86.4 21 16 95 10 4 1012.7 0 0 0 0 0 19.4 19.3 15.7 16.3 13.9 22 02       1.25    . 1
14 14 44.6 86.3 20 15 97    4 1012.7 0 0 0 0 0 20.0 19.8 16.9 17.3 13.9 20 02       1.15    . 1
14 15 44.6 86.3 20 19 97      1012.5 0 0 0 0 0 20.0 19.8 16.6 17.1 13.1 20 03       1.02    . 1
15 08 44.7 86.2 06 05 98      1017.9 2 0 0 0 9 19.5 18.1 15.0 15.2 10.3 36 00       0.47    . 1
15 13 45.2 86.7 10 04 99      1018.8 1 1 0 3 1 19.7 19.5 18.5 21.1 11.2 00 00       1.18    . 1
15 18 45.5 86.6 19 08 99      1017.2 2 2 0 3 9 20.1 20.1 19.3 20.2 11.9 18 00       0.30    . 1
16 08 45.6 86.4 14 05 98      1019.0 5 5 0 5 8 17.3 17.0 16.9 17.3 10.9 00 00       0.45    . 1
16 13 45.7 85.8 17 04 99      1017.8 5 0 0 0 8 18.8 18.3 18.3 19.8 11.7 00 00       1.30    . 1
16 19 45.3 85.4 34 03 99      1013.8 7 7 0 3 8 20.3 20.1 19.2 19.8 11.2 36 00       0.00    . 1
17 07 45.4 85.2 17 08 98      1009.5 8 8 6 X X 19.2 18.9 18.3 18.3 14.2 15 00       0.00    . 1
17 13 45.7 85.8 23 13 96 10 4 1007.4 8 8 5 X X 19.3 19.2 18.5 18.4 15.0 22 00       1.25    . 1
18 14 45.8 84.7 00 09 98      1012.1 8 8 6 X X 16.6 16.6 18.3 18.1 13.6 34 00       0.57    . 1
19 07 45.4 85.0 00 18 98      1012.8 2 2 5 X X 15.3 15.9 18.2 17.5 07.0 36 01       0.00    . 1
19 13 44.9 85.4 01 12 99      1014.8 5 5 0 2 8 17.0 17.4 19.4 19.7 06.4 36 00       0.62    . 1

                                     SEPTEMBER 1965

07 07 43.0 86.2 18 09 96 10 8 1022.2 8 8 7 2 X 17.6 17.6 16.8 16.7    . 18 01       0.00    . 1
07 08 42.8 86.2 20 12 96 10 8 1021.8 8 8 5 2 X 18.4 18.2 17.8 17.8    . 18 01          .    . 1
07 11 42.8 86.4 20 14 97 61 8 1021.5 8 8 5 3 X 18.6 18.4 17.8 17.8    . 18 01       0.02    . 1
07 13 42.8 86.7 21 16 97 10 6 1019.8 8 8 0 3 X 19.0 18.9 18.2 18.8    . 18 01       0.32    . 1
07 15 42.8 86.9 22 12 97 05 4 1019.0 5 5 0 3 1 20.1 20.2 18.7 19.2 19.5 22 01 18 01 0.31    . 1
07 17 42.7 87.4 23 06 97 05   1019.0 7 7 2 3 0 19.9 20.0 19.9 19.8 19.2 23 00 18 01 0.26    . 1
07 19 42.7 87.5 02 22 98      1019.8 8 8 6 X X 17.9 17.9 17.0 16.9 17.3 04 01 22 01 0.00    . 1
09 07 43.0 87.7 21 11 95 46 4 1013.1 9 9 X X X 18.7 18.1 18.2 17.2 19.4 18 00 15 00 0.00 0.00 1
09 13 43.0 86.6 20 16 96 10 4 1011.1 5 5 0 3 9 20.4 20.2 18.1 18.3 19.3 22 01 16 01 0.85 0.65 1
11 12 43.0 86.6 12 11 99      1027.3 4 0 0 0 5 13.5 14.1 12.5 12.3 05.2 12 00 04 01 1.16 0.80 1
11 20 43.0 86.6 09 12 99      1025.0 6 0 0 0 5 17.1 16.8 17.5 17.7 08.4 09 00 04 01 0.00 -.13 1
12 07 43.0 86.4 10 14 99      1024.1 0 0 0 0 0 13.0 13.4 16.2 16.2 08.7 09 01       0.00 -.04 1
12 13 42.8 87.2 08 14 99      1022.0 2 0 0 0 1 17.4 17.3 18.5 18.7 09.1 07 01       1.10 1.00 1
13 07 43.1 87.8 06 04 98      1019.5 4 4 0 3 0 17.3 16.6 15.6 16.2 15.3 30 00 09 01 0.01 -.07 1
13 13 43.3 87.3 18 03 97      1018.0 0 0 0 0 0 19.0 19.1 19.2 19.8 16.7 00 00 09 00 1.05 0.99 1
13 16 43.7 87.6 20 07 97      1015.0 1 0 0 0 1 18.7 19.0 18.3 18.3 16.7 20 00       0.60 0.52 1
14 07 43.7 87.5 36 14 98      1017.1 8 8 5 X X 14.0 14.8 16.8 15.0 11.4 02 02       0.00 0.00 1
15 07 43.8 87.6 26 24 99      1002.6 8 8 5 X X 13.1 13.1 13.0 12.5 08.9 26 00 30 01 0.00 0.00 1
15 11 44.4 87.4 24 09 99      1004.2 8 8 5 X X 13.1 13.3 13.3 12.6 07.9 27 01       0.58 0.56 1
16 09 44.4 87.1 09 13 98      1022.0 8 8 5 X X 09.5 09.4 15.0    . 06.3 04 02 04 02 0.40 0.32 1
16 13 44.5 86.6 12 08 99           . 8 8 5 X X 09.8 09.9 15.3    . 04.9                   0.63 0.59 1
16 15 44.6 86.3 12 11 99      1022.0 8 8 5 X X 11.7 11.8 14.3 14.8 05.8 09 01 09 01 0.37 0.34 1
17 07 44.5 86.3 16 10 97      1018.6 8 8 6 X X 15.0 15.1 15.0 13.7 13.3 15 00 22 01 0.00 0.00 1
17 11 43.9 86.5 18 09 96 10 4 1019.7 8 8 5 X X 15.7 15.6 14.3 14.8 15.0 18 01 18 03 0.35 0.38 1
17 13 43.9 85.4 18 15 96 45 4 1018.2 9 9 X X X 17.3 16.7 15.0 14.6 16.0 18 01 19 02 0.83 0.85 1
20 07 43.9 86.6 15 07 91 45 4 1015.5 8 8 5 2 X    .    .    . 14.5    . 15 00 20 01    .    . 1
23 13 43.1 86.3 26 25 99      1016.0 0 0 0 0 0 16.5    . 16.9    . 09.0 23 08       1.05 0.61 1
27 13 43.1 86.4 12 14 98      1030.0 8 8 0 2 5 09.7    . 15.0 14.7 02.1 12 02       0.27    . 1
29 13 43.1 86.4 15 07 94 10   1015.4 6 6 5 0 0 16.1    . 15.0    . 15.0 12 00       0.79    . 1
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TIMES LOCATIONS WINDS WEATHER PRESSR OKT CLOUD TEMPERATURES (DEGREES C) WAVES SWELL RADIATION V
DY HR LATD LONG DD FF VV WW W PPPPPP N A L M H AIRM AIRB WATI WATS TDPT DD HH QD HH SOLR NETR V

                                  OCTOBER 1965

04 07 43.1 86.3 05 08 98      1027.0 6 6 5 0 0 05.6  .   14.0  .   00.6 04 00       0.01  .   1
04 08 43.2 86.5 04 08 98      1027.5 7 7 5 0 0 05.9  .   14.3  .   00.2 04 01       0.10  .   1
04 13 43.9 96.5 36 16 98      1027.3 8 8 5 X X 05.6  .   13.0  .   00.6 36 02       0.40  .   1
04 13 43.1 86.3 15 06           .              07.1 07.4 14.3  .   -0.7             0.47  .   2
04 18 44.6 86.3 03 10 98      1026.9 7 7 5 0 0 05.5  .   13.0  .   -0.8 03 00 36 01 0.00  .   1
04 19 44.6 86.3 03 08 98      1026.5 6 6 5 0 0 05.4  .   12.6  .   -1.2 03 00 36 00 0.00  .   1
05 07 44.5 86.4 14 07 98      1025.2 2 2 5 0 0 04.6  .   13.1  .   00.5 12 00       0.00  .   1
05 09 44.5 86.6 15 09 98      1025.7 7 7 5 0 0 04.7  .   12.2  .   00.5 12 00       0.23  .   1
05 11 44.5 86.9 13 07 98      1024.7 8 8 5 X 0 06.1  .   12.3  .   02.2 12 00       0.55  .   1
05 13 44.4 87.1 17 08 98      1023.3 8 8 5 0 7 06.5  .   11.6  .   01.6 07 00 XX 01 0.90  .   1
05 13 43.0 86.3 26 10           .              08.7 09.4 14.2  .   02.4             0.52  .   2
08 13 43.2 87.7 30 22 98      0991.7 8 8 5 X X 11.6  .   08.8  .   06.5 27 01       0.28  .   1
10 07 42.7 87.5 32 08 97      1013.2 2 2 0 2 1 10.1  .   10.6  .   07.1       04 02 0.00  .   1
10 09 42.7 87.4 32 04 98      1014.6 0 0 0 0 0 11.7  .   13.6  .   05.0 32 00 02 02 0.40  .   1
10 11 42.8 85.9 28 05 98      1015.3 0 0 0 0 0 12.7  .   13.1  .   04.8 28 00 36 02 0.80  .   1
10 13 42.8 86.6 23 04 98      1014.4 0 0 0 0 0 12.2  .   14.0  .   05.6 23 00 36 01 0.85  .   1
10 14 42.8 86.4 23 08 98      1013.9 0 0 0 0 0 11.6  .   13.6  .   05.6 23 00 36 00 0.82  .   1
10 16 42.8 86.2 20 11 98      1013.0 0 0 0 0 0 12.3  .   14.0  .   06.9 20 00       0.40  .   1
11 13 43.2 86.7 28 18 98      1014.5 0 0 0 0 0 12.4  .   12.9  .   04.6 32 03       0.95  .   1
11 13 42.4 86.4 26 11           .              12.7 12.9 13.9  .   05.7             1.05  .   2
11 15 42.4 86.5 28 13           .              13.4 13.6 14.2  .   02.7             0.80  .   2
11 16 42.4 86.4 28 14           .              13.6 13.8 13.9  .   04.0             0.48  .   2
13 07 42.4 86.3 15 10           .              08.2 08.4 13.2  .   02.0             0.00  .   2
13 10 42.1 86.5 06 07           .              11.4 11.6 12.8  .   05.0             0.48  .   2
13 11 42.1 86.6 21 05           .              11.1 11.3 13.4  .   04.9             0.62  .   2
13 13 42.0 86.7 29 03           .              11.7 11.6 13.8  .   05.2             0.95  .   2
13 13 43.6 86.9 03 05 99      1018.6 0 0 0 0 0 08.1  .   11.0  .   01.2 00 00 33 01 0.80  .   1
13 14 43.8 87.0 03 04 99      1018.5 0 0 0 0 0 08.3  .   11.9  .   01.5 03 00 33 00 0.82  .   1
13 19 41.8 87.1 05 11           .              12.3 12.4 12.8  .   05.7             0.00  .   2
14 07 43.7 87.4 13 12 98      1016.5 4 4 0 3 1 11.1  .   09.9  .   08.9 12 01       0.00  .   1
14 08 41.8 87.4 27 10           .              11.5 11.6 11.9  .   05.6             0.07  .   2
14 10 43.9 86.8 15 17 98      1015.0 8 8 0 3 1 10.5  .   11.0  .   07.1 16 02       0.47  .   1
14 10 41.9 87.3 27 05           .              12.3 12.3 12.7  .   07.4             0.50  .   2
14 12 43.9 86.6 16 20 97      1014.0 8 8 0 5 5 12.8  .   11.7  .   08.0 18 03       0.60  .   1
14 13 43.9 86.5 17 20 98      1013.3 8 8 0 5 5 14.1  .   11.3  .   07.2 18 03       0.25  .   1
14 13 42.0 87.2 20 13           .              14.7 14.5 12.6  .   09.2             0.77  .   2
15 09 42.3 87.7 27 09           .              14.2 13.5 10.2  .   10.1             0.42  .   2
15 10 42.3 86.7 27 06           .              13.8 13.1 10.3  .   10.6             0.63  .   2
15 11 42.3 87.5 25 09           .              12.1 12.1 12.1  .   10.0             0.77  .   2
15 13 42.3 87.3 22 05           .              13.5 13.6 13.5  .   11.7             0.85  .   2
15 16 42.3 87.0 14 03           .              14.4 14.4 14.4  .   10.3             0.25  .   2
15 19 42.6 86.6 02 04           .              13.5 13.6 13.6  .   08.7             0.00  .   2
19 07 43.1 86.3 13 08 97 05   1021.5 5 0 0 0 2 14.0  .   13.6  .   09.9 15 00       0.00  .   1
19 13 44.0 87.1 15 12 96 05   1019.0 6 0 0 0 2 15.0  .   10.9  .   10.4 15 00       0.72  .   1
19 13 43.1 86.3 12 08           .              18.3 17.6 13.8  .   09.3             0.92  .   2
20 07 44.2 87.4 17 13 91 45 4 1012.8 9 9 X X X 12.0  .   09.3  .   11.8 15 01       0.00  .   1
20 13 43.9 87.3 19 12 94 44 4 1012.8 4 4 0 3 0 13.4  .   11.3  .   12.3 20 02       0.72  .   1
22 19 43.3 86.6 25 37 98      1004.8 3 3 0 2 5 09.9  .   12.6  .   05.4 25 00 36 01 0.00  .   1
26 13 42.7 86.8 35 15 99      1022.0 6 6 5 0 0 09.3 09.  12.4  .   05.0 36 01 33 04 0.35  .   1
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| TIMES | | LOCATIONS | | WINDS | | WEATHER | | | PRESSR | OKT | CLOUD | | | | TEMPERATURES (DEGREES C) | | | | | WAVES | | SWELL | | RADIATION | | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DY | HR | LATD | LONG | DD | FF | VV | Ww | W | PPPPPP | N | A | L | M | H | AIRM | AIRB | WATI | WATS | TDPT | DD | HH | DD | HH | SOLR | NETR | V |

NOVEMBER 1965

| DY | HR | LATD | LONG | DD | FF | VV | Ww | W | PPPPPP | N | A | L | M | H | AIRM | AIRB | WATI | WATS | TDPT | DD | HH | DD | HH | SOLR | NETR | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 13 | 42.7 | 86.8 | 26 | 13 | 98 | | | 1023.5 | 0 | 0 | 0 | 0 | 0 | 09.2 | 09.7 | 10.2 | . | 02.2 | 25 | 01 | 36 | 02 | 0.75 | . | 2 |
| 04 | 11 | 43.2 | 86.5 | 01 | 10 | 98 | | | 1034.0 | 2 | 2 | 5 | 0 | 0 | 05.5 | . | 11.0 | . | -1.6 | 03 | 01 | 36 | 03 | 0.60 | . | 1 |
| 04 | 12 | 43.1 | 86.3 | 01 | 06 | 98 | | | 1034.3 | 1 | 1 | 3 | 0 | 0 | 06.1 | . | 11.4 | . | -1.9 | 01 | 00 | 36 | 02 | 0.78 | . | 1 |
| 04 | 13 | 42.5 | 86.3 | 35 | 07 | | | | . | | | | | | 09.8 | 07.2 | 10.9 | . | -1.5 | | | | | 0.87 | . | 2 |
| 04 | 14 | 42.4 | 86.3 | 02 | 15 | | | | . | | | | | | 06.6 | 06.8 | 11.3 | . | -2.2 | | | | | 0.70 | . | 2 |
| 04 | 15 | 42.4 | 86.4 | 01 | 12 | | | | . | | | | | | 06.8 | 07.1 | 11.4 | . | -1.5 | | | | | 0.55 | . | 2 |
| 04 | 17 | 42.4 | 86.5 | 01 | 10 | | | | . | | | | | | 07.5 | 07.6 | 11.1 | . | -1.6 | | | | | 0.05 | . | 2 |
| 05 | 07 | 42.4 | 86.2 | 13 | 16 | | | | . | | | | | | 02.5 | 02.7 | 10.7 | . | -3.2 | | | | | 0.00 | . | 2 |
| 05 | 08 | 42.1 | 86.5 | 15 | 14 | | | | . | | | | | | 03.3 | 03.8 | 10.7 | . | -2.2 | | | | | 0.03 | . | 2 |
| 05 | 09 | 42.1 | 86.6 | 16 | 16 | | | | . | | | | | | 05.7 | 05.8 | 10.3 | . | -1.1 | | | | | 0.12 | . | 2 |
| 05 | 11 | 42.0 | 86.7 | 17 | 12 | | | | . | | | | | | 08.1 | 08.2 | 10.1 | . | 01.0 | | | | | 0.55 | . | 2 |
| 05 | 13 | 42.0 | 87.1 | 17 | 13 | | | | . | | | | | | 09.4 | 09.6 | 09.8 | . | 02.9 | | | | | 0.70 | . | 2 |
| 05 | 16 | 41.9 | 87.3 | 15 | 07 | | | | . | | | | | | 12.4 | 11.7 | 09.9 | . | 07.0 | | | | | 0.40 | . | 2 |
| 05 | 17 | 41.8 | 87.4 | 19 | 08 | | | | . | | | | | | 15.2 | 13.4 | 09.6 | . | 06.6 | | | | | 0.00 | . | 2 |
| 06 | 10 | 42.8 | 86.2 | 25 | 10 | 92 | 45 | 4 | 1024.4 | 9 | 9 | X | X | X | 11.7 | . | 11.4 | . | 10.7 | 24 | 01 | | | 0.30 | . | 1 |
| 06 | 11 | 42.8 | 86.3 | 21 | 09 | 92 | 45 | 4 | 1024.5 | 9 | 9 | X | X | X | 11.3 | . | 12.1 | . | 10.3 | 25 | 01 | | | 0.40 | . | 1 |
| 06 | 12 | 42.8 | 86.4 | 19 | 11 | 92 | 45 | 4 | 1024.2 | 9 | 9 | X | X | X | 11.1 | . | 10.8 | . | 10.3 | 19 | 00 | 24 | 01 | 0.84 | . | 1 |
| 06 | 13 | 42.8 | 86.6 | 19 | 10 | 92 | 45 | 4 | 1023.6 | 9 | 9 | X | X | X | 11.2 | . | 10.7 | . | 09.9 | 19 | 00 | 24 | 01 | 0.62 | . | 1 |
| 06 | 13 | 42.1 | 87.7 | 22 | 07 | | | | . | | | | | | 13.6 | 12.6 | 10.1 | . | 08.0 | | | | | 0.28 | . | 2 |
| 06 | 15 | 42.8 | 86.9 | 20 | 11 | 94 | 10 | 4 | 1022.5 | 9 | 9 | X | X | X | 11.4 | . | 10.4 | . | 10.3 | 25 | 00 | | | 0.50 | . | 1 |
| 06 | 16 | 42.3 | 87.7 | 22 | 10 | | | | . | | | | | | 15.7 | 14.1 | 09.7 | . | 09.1 | | | | | 0.22 | . | 2 |
| 06 | 17 | 42.3 | 87.6 | 23 | 11 | | | | . | | | | | | 13.4 | 12.2 | 09.3 | . | 07.5 | | | | | 0.07 | . | 2 |
| 06 | 18 | 42.7 | 87.4 | 19 | 05 | 96 | 05 | 4 | 1022.6 | 8 | 8 | 5 | X | X | 12.3 | . | 09.6 | . | 10.2 | 22 | 00 | | | 0.00 | . | 1 |
| 06 | 19 | 42.7 | 87.5 | 21 | 06 | 96 | 05 | | 1023.0 | 8 | 8 | 5 | X | X | 12.4 | . | 09.4 | . | 10.7 | 22 | 00 | | | 0.00 | . | 1 |
| 06 | 19 | 42.3 | 87.4 | 21 | 07 | | | | . | | | | | | 12.4 | 11.4 | 09.0 | . | 06.5 | | | | | 0.00 | . | 2 |
| 07 | 00 | 43.6 | 87.5 | 36 | 14 | 91 | 61 | 6 | 1023.0 | 9 | 9 | X | X | X | 08.5 | . | 07.9 | . | 08.0 | 36 | 00 | | | 0.00 | . | 1 |
| 07 | 00 | 42.3 | 87.0 | 16 | 05 | | | | . | | | | | | 11.2 | 11.0 | 10.5 | . | 06.8 | | | | | 0.00 | . | 2 |
| 07 | 01 | 42.3 | 86.7 | 20 | 10 | | | | . | | | | | | 12.3 | 12.0 | 11.0 | . | 08.1 | | | | | 0.00 | . | 2 |
| 07 | 01 | 43.6 | 87.5 | 04 | 12 | 97 | 61 | 6 | 1022.6 | 8 | 8 | 5 | X | X | 07.9 | . | 08.2 | . | 07.0 | 04 | 01 | | | 0.00 | . | 1 |
| 07 | 02 | 42.4 | 86.5 | 20 | 08 | | | | . | | | | | | 11.8 | 11.8 | 10.8 | . | 07.7 | | | | | 0.00 | . | 2 |
| 07 | 04 | 43.8 | 87.0 | 02 | 09 | 98 | | | 1023.0 | 8 | 8 | 0 | 5 | X | 08.5 | . | 07.9 | . | 06.6 | 04 | 01 | | | 0.00 | . | 1 |
| 07 | 07 | 44.1 | 87.2 | 06 | 18 | | | | . | 3 | 3 | 5 | 3 | 0 | 07.5 | . | 08.5 | . | 04.4 | 04 | 03 | | | 0.00 | . | 1 |
| 08 | 00 | 44.4 | 87.4 | 12 | 09 | 98 | 61 | | 1013.8 | 8 | 8 | 5 | X | X | 07.5 | . | 07.6 | . | 04.1 | 12 | 00 | 04 | 02 | 0.00 | . | 1 |
| 08 | 01 | 44.4 | 87.1 | 14 | 15 | 98 | 60 | 6 | 1016.8 | 8 | 8 | 5 | X | X | 07.7 | . | 08.9 | . | 03.9 | 15 | 01 | 04 | 02 | 0.00 | . | 1 |
| 08 | 03 | 44.5 | 86.9 | 19 | 23 | 98 | | | 1015.0 | 8 | 8 | 5 | X | X | 08.4 | . | 09.3 | . | 06.7 | 18 | 03 | | | 0.00 | . | 1 |
| 09 | 13 | 44.6 | 86.3 | 00 | 00 | 98 | | | 1025.8 | 8 | 8 | 5 | X | X | 00.0 | . | 07.2 | . | -6.1 | 33 | 01 | 18 | 00 | 0.10 | . | 1 |
| 09 | 15 | 44.5 | 86.6 | 22 | 09 | 98 | | | 1024.5 | 6 | 6 | 5 | 0 | 0 | 00.6 | . | 09.0 | . | -6.3 | 22 | 00 | | | 0.10 | . | 1 |
| 09 | 19 | 44.0 | 86.8 | 21 | 08 | 98 | | | 1023.9 | 5 | 5 | 5 | 0 | 0 | 02.3 | . | 07.8 | . | -4.0 | 22 | 01 | | | 0.00 | . | 1 |
| 09 | 20 | 43.9 | 86.8 | 21 | 12 | 98 | | | 1023.7 | 8 | 8 | 5 | X | X | 02.7 | . | 07.4 | . | -3.2 | 22 | 01 | | | 0.00 | . | 1 |
| 09 | 21 | 43.9 | 86.6 | 21 | 07 | 98 | | | 1023.5 | 8 | 8 | 5 | X | X | 02.7 | . | 09.6 | . | -3.2 | 22 | 00 | | | 0.00 | . | 1 |
| 09 | 22 | 43.9 | 86.5 | 20 | 09 | 98 | | | 1023.2 | 8 | 8 | 5 | X | X | 03.4 | . | 09.3 | . | -2.6 | 22 | 00 | | | 0.00 | . | 1 |
| 10 | 01 | 43.4 | 86.5 | 10 | 10 | 98 | | | 1023.0 | 8 | 8 | 5 | X | X | 02.5 | . | 10.1 | . | -3.0 | 14 | 01 | | | 0.00 | . | 1 |

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| DY | HR | LATD | LONG | DD | FF | VV | Ww | W | PPPPPP | N | A | L | M | H | AIRM | AIRB | WATI | WATS | TDPT | DD | HH | DD | HH | SOLR | NETR | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 12 | 42.8 | 86.4 | | | | | | . | | | | | | 07.7 | 08.9 | 03.7 | . | 02.9 | | | | | 0.79 | . | 1 |
| 21 | 13 | 42.8 | 86.6 | | | | | | . | | | | | | 06.3 | 06.6 | 02.4 | . | 03.3 | | | | | 0.96 | . | 1 |
| 21 | 15 | 42.8 | 86.9 | | | | | | . | | | | | | 05.7 | 07.9 | 07.5 | . | 03.1 | | | | | 0.26 | . | 1 |
| 22 | 10 | 42.2 | 87.5 | | | | | | . | | | | | | 02.0 | 04.8 | 02.7 | . | 02.4 | | | | | 0.11 | . | 1 |
| 25 | 10 | 42.3 | 87.5 | | | | | | . | | | | | | -5.1 | -4.5 | 03.1 | . | -9.9 | | | | | 0.5[illegible] | . | 1 |
| 25 | 13 | 41.9 | 87.4 | | | | | | . | | | | | | -2.3 | 05.1 | 04.2 | . | -9.9 | | | | | 0.98 | . | 1 |
| 25 | 14 | 41.8 | 87.4 | | | | | | . | | | | | | -1.0 | 02.3 | 03.3 | . | -9.6 | | | | | 0.60 | . | 1 |
| 27 | 10 | 41.9 | 87.3 | | | | | | . | | | | | | -1.9 | -0.1 | 01.7 | . | -5.3 | | | | | 0.76 | . | 1 |
| 27 | 13 | 42.0 | 86.8 | | | | | | . | | | | | | -2.5 | 00.0 | 03.4 | . | -8.5 | | | | | 1.27 | . | 1 |
| 27 | 14 | 42.0 | 86.7 | | | | | | . | | | | | | -2.6 | -0.1 | 01.8 | . | -8.1 | | | | | 1.09 | . | 1 |
| 27 | 15 | 42.1 | 86.6 | | | | | | . | | | | | | -2.5 | 00.1 | 02.4 | . | -7.2 | | | | | 0.95 | . | 1 |
| 27 | 19 | 41.8 | 87.1 | | | | | | . | | | | | | -1.7 | 00.6 | 02.0 | . | -9.5 | | | | | 0.00 | . | 1 |
| 28 | 13 | 41.7 | 86.9 | | | | | | . | | | | | | -0.2 | 00.9 | 02.2 | . | -9.3 | | | | | 1.22 | . | 1 |
| 28 | 14 | 41.8 | 86.7 | | | | | | . | | | | | | -0.2 | 02.0 | 03.0 | . | -9.7 | | | | | 1.07 | . | 1 |
| 28 | 15 | 41.8 | 86.8 | | | | | | . | | | | | | -0.3 | -0.2 | 01.8 | . | -7.6 | | | | | 0.93 | . | 1 |
| 29 | 07 | 41.9 | 87.4 | | | | | | . | | | | | | 02.1 | 02.2 | 01.4 | . | -2.5 | | | | | 0.01 | . | 1 |
| 29 | 13 | 42.4 | 86.5 | | | | | | . | | | | | | 02.4 | 08.6 | 03.0 | . | 01.2 | | | | | 0.13 | . | 1 |

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TIMES LOCATIONS WINDS WEATHER PRESSR CKT CLOUD TEMPERATURES (DEGREES C) WAVES SWELL RADIATION V
DY HR LATD LONG DD FF VV WW W PPPPPP N A L M H AIRM AIRB WATI WATS TDPT DD HH DD HH SOLR NETR V

29 15 42.4 86.3                   .            01.3 07.3 03.5   .  00.5             0.08  .   1

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04 11 42.8 86.2 30 10             .            01.0 01.2 03.1   .  -2.5             0.64  .   2
04 13 42.6 86.2 30 11                          01.5 01.6 02.7   .  -3.0             0.89  .   2
04 13 43.4 86.5                   .            01.2   .  01.2   .  -1.9             0.93  .   1
04 16 43.9 86.6                   .            01.3   .  01.4   .  -1.2             0.32  .   1
04 17 42.2 86.4 25 08             .            02.1 02.2 03.2   .  -1.6             0.41  .   2
05 09 41.9 86.6 30 12             .            01.5 01.7 03.2   .  -0.1             0.28  .   2
05 13 41.7 87.1 31 16             .            00.2 00.3 03.2   .  00.3             0.19  .   2
06 12 41.6 87.3                   .            02.3 02.4 02.7   .  -1.9             0.03  .   2
06 13 41.7 87.4 24 23             .            02.2 02.3 03.2   .  -1.3             0.22  .   2
07 11 41.8 87.3 29 16             .            01.7 01.8 02.4   .  -2.2             0.41  .   2
07 12 41.9 87.2 30 18             .            01.7 01.8 02.3   .  -2.0             0.95  .   2
07 13 41.8 87.1 34 12             .            02.6 02.8 02.5   .  -0.6             1.13  .   2
08 13 42.4 86.6 25 07             .            02.7 02.7 02.7   .  -1.2             1.20  .   2
12 07 42.8 86.4 07 16             .            00.5 00.7 02.5   .  -2.2             0.12  .   2
12 09 42.8 86.4 06 18             .            02.2 02.3 02.3   .  -0.9             0.50  .   2
14 11 42.8 86.9 06 04             .            03.2 03.3 03.2   .  01.7             0.97  .   2
14 13 42.8 87.1 00 00             .            03.3 03.4 03.3   .  01.3             1.17  .   2
14 16 42.7 87.4 05 07             .            03.5 03.6 02.9   .  01.6             0.67  .   2
14 19 42.4 87.7 03 06             .            03.3 03.3 03.7   .  00.7             0.03  .   2
15 07 42.3 87.7 32 05             .            02.7 02.7 02.7   .  01.3             0.04  .   2
15 09 42.3 87.5 32 03             .            03.2 03.2 02.8   .  03.5             0.66  .   2
15 12 42.3 87.0 36 05             .            03.4 03.5 03.3   .  02.6             1.10  .   2
15 13 42.3 87.0 33 11             .            03.2 03.3 03.4   .  02.2             0.23  .   2
16 11 42.0 87.1 31 10 97 05 0     .    0 0 0     .  08.5 02.3   .    .  30 01          .    .   1
16 13 41.8 87.4 09 08 97 05 0     .    0 0 0     .  11.0 03.6   .    .        30 01   .    .   1
16 13 42.9 86.5 07 12             .            03.1 03.0 02.7   .  01.6             1.21  .   2
17 12 42.1 86.7 11 07 97 05 0     .  0 0 0 0 0   .  09.7   .  03.5   .  11 00          .    .   1
17 13 42.1 86.6 14 06 97 05 0     .  0 0 0 0 0   .  09.6   .  03.3   .  14 00          .    .   1
19 09 42.7 86.2 10 20             .            02.2 10.9 03.8   .  10.2             0.07  .   2
19 13 42.3 87.0                   .            08.1 07.3 03.6   .  08.0             0.41  .   1
19 13 42.3 86.3 06 09                          11.4 09.7 04.5   .  09.6             0.19  .   2
20 07 42.1 86.4 16 12             .            15.0 13.4 06.0   .  11.1             0.06  .   2
20 13 42.6 87.7                   .            06.8 05.7 04.0   .  05.6             0.27  .   1
20 13 43.0 86.2 29 02             .            06.3 06.2 04.8   .  06.8             0.48  .   2
20 19 42.8 86.6                   .            09.1 08.1 02.7   .  08.3             0.00  .   1
22 07 43.0 86.3 12 05             .            02.9 03.0 03.3   .  00.8             0.08  .   2
22 13 43.3 86.4 26 09                          03.4 03.4 02.7   .  01.8             1.21  .   2
25 07 42.9 86.2 18 02             .            05.3 04.8 05.8   .  06.5             0.19  .   1
25 07 43.0 86.3 24 08 98 05 0 1020.2 0 0 0 0 0 05.3 04.3 02.7   .  02.5 00 00 32 00 0.18  .   2
25 13 42.8 86.9 19 11             .            07.0 05.6 03.5   .  02.7             1.24  .   1
25 13 42.3 87.1 15 06 98 05 0 1022.2 0 0 0 0 0 09.5 06.7 03.4   .  03.7 00 00 32 00 1.21  .   2
25 15 42.7 87.4 16 13             .            08.3 06.1 02.9   .  02.1             1.06  .   1
25 16 42.7 87.5 15 10             .            07.8 06.3 03.1   .  02.5             0.78  .   1
26 11 42.0 87.1 04 21 98 02 2 1019.5 8 8 0 2 X 05.6 05.5 03.0   .  03.2 04 02       0.29  .   2
26 12 42.0 87.1 04 22 98 02 2 1019.7 8 8 0 2 X 06.0 06.7 03.1   .  03.5 04 04       0.33  .   2
28 13 43.6 87.5 26 16             .            06.7 06.1 02.7   .  -1.0             1.37  .   1
29 07 43.7 87.4 31 03             .            04.0 02.3 02.4   .  -0.5             0.24  .   1
29 07 41.8 87.5 02 09 98 02 2 1030.6 8 0 0 7 X 06.5 06.7 07.7   .  02.1 02 00 XX 00 0.18  .   2
29 09 43.8 87.0 10 08             .            03.7 03.4 02.7   .  00.2             0.85  .   1
29 12 43.9 86.6 31 08                          04.9 03.6 02.7   .  00.4             1.30  .   1
29 13 43.9 86.6 28 07             .            04.3 03.9 03.0   .  -0.5             1.24  .   1
29 13 42.1 86.6 12 08 98 02 2 1027.8 8 0 0 7 X 11.9 10.7 05.6   .  03.8 12 00 09 00 1.23  .   2
29 17 42.4 86.5 25 07             .            10.3 09.2 03.6   .  03.2             0.20  .   2
30 07 42.3 86.6 10 05             .            06.6 06.3 03.7   .  05.2             0.04  .   2
30 07 44.4 87.2 35 08             .            04.0 04.0 03.2   .  04.0             0.01  .   1
30 09 42.3 87.0 30 09             .            06.3 06.0 03.5   .  05.9             0.11  .   2
30 10 42.3 87.0 31 08             .            04.8 04.7 03.4   .  04.9             0.17  .   2
30 11 44.5 86.6 33 09             .            05.1 05.0 04.2   .  05.3             0.68  .   1
30 13 44.5 86.4 33 11             .            05.3 04.9 04.0   .  04.6             0.22  .   1
30 13 42.3 87.4 34 11             .            05.1 05.1 03.3   .  03.8             0.60  .   2
30 15 42.3 87.5 36 10             .            04.9 04.9 03.3   .  03.5             0.79  .   2
30 14 44.6 86.3 34 13             .            04.7 04.7 04.0   .  03.2             0.28  .   1
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TIMES LOCATIONS WINDS WEATHER PRESSR CKT CLOUD TEMPERATURES (DEGREES C) WAVES SWELL RADIATION V
DY HR LATD LUNG DD FF VV WW W PPPPPP N A L M H AIRM AIRB WATI WATS TDPT DD HH DD HH SOLR NETR V

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01 01 42.4 87.4 26 06             .            02.9 03.0 02.9   .  02.3             0.00  .   2
01 07 42.8 86.3 04 08             .            02.2 02.4 03.3   .  -2.1             0.15  .   2
02 07 44.6 86.3 13 08             .            01.8 01.9   .    .  -2.2             0.20  .   1
02 13 44.6 86.5 20 10             .            03.7 03.7   .    .  00.1             0.74  .   1
04 07 44.7 86.1 20 05             .            02.9 02.9   .    .  00.5             0.24  .   1
04 13 43.0 86.2 22 08 98 02 2 1034.0 2 0 0 0 1 04.0 04.2 05.1   .  -1.2 22 00        .    .   2
04 13 44.8 86.9 17 12             .            04.9 04.7   .    .  00.4             1.10  .   1
06 13 45.1 87.3 06 09             .            03.8 03.9   .    .  00.4             1.22  .   1
09 13 43.3 86.4 33 25 98 02 2 1025.0 3 3 1 0 0 01.4 02.7 03.7   .  01.6 34 04       0.93  .   2
10 13 42.5 86.7 15 02 98 00 0 1028.8 0 0 0 0 0 02.8 02.6 04.2 05.2 -3.4 15 00 34 00 1.29 1.23 2
10 19 41.9 87.6 08 15 98 03 1 1025.8 7 0 0 0 4 05.2 05.5 08.6   .  -1.5 08 01       0.09 0.00 2
11 07 41.9 87.6 12 19 96 61 6 1023.0 8 8 6 X X 03.2 03.9 09.0   .  02.3 12 03        .    .   2
11 13 41.9 87.6 12 17 96 61 6 1019.0 8 8 6 X X 05.2 05.7   .    .  04.3 13 04        .    .   2
13 13 42.1 86.7 08 02 96 95 4 1018.2 9 9 X X X 05.0 05.1 03.8   .  03.8 00 00 08 01 0.06  .   2
13 19 42.9 86.2 22 04 98 02 2 1017.1 8 8 8 X X 05.0 04.7 04.0   .  03.6 00 00       0.01  .   2
16 11 42.8 86.4 26 09             .            08.6 07.9 05.1   .    .               1.09  .   1
16 13 42.8 86.8 24 09 98 00 0 1012.4 0 0 0 0 0 09.1 08.2 05.4 04.3   .  24 00        .    .   1
16 13 42.4 86.5 24 07 98 00 0 1013.1 0 0 0 0 0 08.5 07.8 05.4   .  05.0 24 00 27 01 1.33 1.28 2
16 14 42.8 87.1 15 04             .            09.0 07.6 05.6   .    .               1.16  .   1
16 17 42.3 87.0 19 07 98 00 0 1012.8 0 0 0 0 0 09.3 07.7 03.8   .  04.7 19 00 27 00 0.49 0.52 2
16 19 42.3 87.3 19 05 98 03 0 1013.0 2 2 0 4 0 13.5 10.1 03.5   .  04.4 00 00 27 00 0.04 0.00 2
16 19 42.9 87.7 27 08 98 10 4 1012.2 2 1 0 4 1 18.5 15.0 06.5   .    .  00 00       0.06  .   1
17 07 43.1 87.7 21 08 98 02 2 1013.0 8 3 8 7 2 10.2 08.5 03.8   .    .  21 00       0.11  .   1
17 07 42.3 87.7 00 00 96 10 4 1013.4 8 8 0 1 X 08.7 08.0 07.2   .  05.9 00 00       0.10 0.07 2
17 09 42.3 87.5 12 08 96 10 4 1014.2 8 8 0 1 X 09.2 07.2 03.9   .  05.1 12 00       0.09 0.12 2
17 13 43.8 87.0 13 11 97 60 4 1014.0 8 5 8 3 X 10.0 08.5 03.6 04.3   .               0.15  .   1
17 13 41.8 87.4 12 12 97 61 2 1012.5 8 5 1 1 X 12.0 11.5 08.3   .  08.5 12 01       0.17 0.19 2
17 19 44.4 86.3 13 08 97 02 3 1011.0 8 3 1 1 X 13.3 08.0 03.4 04.2   .  00 00       0.01  .   1
18 07 44.5 86.3 08 03 92 45 4 1006.0 9 9 X X X 10.0 07.5 03.6   .    .  00 00       0.05  .   1
18 09 44.5 86.6 19 03             .            07.6 06.1 04.2   .    .               0.40  .   1
18 12 44.4 87.1 04 03             .            10.1 08.0 04.1   .    .               1.16  .   1
18 13 44.3 87.1 00 00 93 42 4 1007.0 1 1 1 0 0 10.6 08.6 03.4   .    .  00 00       1.18  .   1
18 13 42.0 86.7 23 05 92 28 4 1009.2 9 9 X X X 08.3 08.0 07.2   .  07.5 23 01       1.15 1.18 2
18 19 43.4 86.5 16 03             .            07.2 06.8 05.6   .    .               0.11  .   1
19 07 41.7 86.9 22 14 98 00 0 1011.7 0 0 0 0 0 11.1 11.1 09.5   .  07.5 22 01       0.29 0.00 2
19 09 41.6 87.3 24 14             .            12.9 12.7 09.9   .  07.7             0.57 0.62 2
19 12 41.6 87.4 23 14             .            16.8 16.8 12.6   .  06.7             1.32 1.25 2
19 13 41.7 87.5 25 18 98 03 0 1011.5 3 3 1 0 1 17.5 17.4 12.1   .  04.9 25 01       1.07 0.59 2
20 13 42.1 87.3 20 05 98 05 2 1013.3 8 0 0 0 2 12.3 10.2 05.8   .  06.9 00 00 XX 00 1.16 1.20 2
20 19 42.7 86.4 21 11 98 10 2 1013.0 8 3 0 7 2 08.2 07.7 05.1   .  05.1 21 01       0.09 0.05 2
23 07 42.9 86.3 13 11 97 05 3 1013.7 8 0 0 0 7 11.0 09.6 05.5   .  08.7 13 01       0.21  .   1
23 13 42.8 86.4 15 12 97 01 0 1011.0 3 0 0 0 8 17.0 13.0 06.5   .  11.4 15 01       1.22  .   1
23 13 42.8 86.4 14 09 97 05 0 1011.0 2 0 0 0 2 15.0 14.1 06.3   .  09.6 14 00 18 00 1.20  .   2
23 19 42.5 87.2 14 16 97 02 1 1003.2 8 8 5 X X 11.7 10.1 04.2   .  07.2 14 03       0.03  .   2
23 20 42.4 87.4 24 50 95 97 2 1005.0 8 8 3 X X 13.9 12.7 04.5   .  09.2 XX 03       0.00  .   2
24 07 43.0 86.4 24 08 97 10 0 1013.0 4 0 0 0 1 08.2 07.6 04.9   .  08.1       24 02 0.17  .   1
24 09 42.9 86.7 26 08 98 02 0 1015.0 2 0 0 0 1 09.2 07.7 04.2   .  08.2 24 00       0.73  .   1
24 10 42.9 86.7 27 07 98 00 0 1016.0 0 0 0 0 0 09.8 07.8 04.0   .  07.6 00 00       0.94  .   1
24 11 42.9 86.7 20 07 98 00 0 1016.0 0 0 0 0 0 08.8 07.9 04.0   .  07.3 00 00       1.19  .   1
24 12 42.9 86.7 26 05 98 03 0 1017.0 2 2 1 0 0 09.6 08.2 04.3   .  07.4 00 00       1.19  .   1
24 13 42.9 86.7 28 08             .            11.1 08.2   .    .  08.1             1.23  .   1
25 07 43.0 86.4 23 09             .            09.7 09.2   .    .  06.5             0.29  .   1
25 13 43.3 87.4 13 05             .            18.0 12.6   .    .  04.2             1.23  .   1
25 13 42.3 87.0 26 08 98 00 0 1019.2 0 0 0 0   16.2 11.9 05.8   .  05.2 00 00       1.30  .   2
26 07 43.2 87.7 25 07 98 02 0 1014.7 4 4 6 3 0 15.3 13.8 08.0   .  08.4 00 00        .    .   1
26 13 43.2 87.7 20 12 98 00 0 1012.0 0 0 0 0 0 18.4 14.7 09.2   .  10.2 00 00        .    .   1
26 13 42.6 87.0 22 10 97 10 0 1013.0 0 0 0 0 0 13.0 10.0 06.0   .  06.5 22 00       1.28  .   2
27 07 43.4 87.7 24 15 98 02 2 1002.0 6 6 1 3 0 17.1 14.4 06.3   .  09.1 24 02        .    .   1
27 13 43.2 86.6 34 19 98 07 1 1015.2 3 3 0 3 0 09.6 08.9 04.8   .  06.9 XX XX        .    .   1
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TIMES LOCATIONS WINDS WEATHER PRESSR CKT CLOUD TEMPERATURES (DEGREES C) WAVES SWELL RADIATION V
DY HR LATD LONG DD FF VV WW W PPPPPP N A L M H AIRM AIRB WATI WATS TDPT DD HH DD HH SOLR NETR V

                                 JUNE 1966

01 07 42.9 86.2 36 06 97 00 0 1023.1 0 0 0 0 0 07.4 07.7 06.5   .  04.8 00 00       0.26   .  1
01 09 42.8 86.4 35 03             .            08.6 08.2   .    .  05.2             0.78   .  1
01 13 42.8 86.9 32 05 99 02 0 1024.3 1 1 7 0 0 09.8 09.5 08.5   .  05.7 00 00       1.20   .  1
01 13 42.8 86.4 32 11 98 01 0 1023.8 1 0 0 0 5 09.2 08.7 09.1   .  04.2 32 01       1.31 1.27 2
01 19 42.2 87.2 36 04 99 00 0 1022.7 0 0 0 0 0 11.3 09.6 08.3   .  06.1 00 00 XX 00 0.20   .  2
02 07 42.8 87.6 20 08 98 02 0 1023.0 2 0 0 0 8 11.2 11.2 09.2   .  05.5 20 00       0.29   .  1
02 12 43.6 87.5 18 11             .            10.6 09.6   .    .  05.4             1.14   .  1
02 13 43.6 87.5 18 11 98 03 1 1021.5 7 7       10.2 09.1 07.4   .  06.3 08 01       1.14   .  1
02 19 44.4 87.1 27 20             .            08.2 07.7   .    .  05.0             0.08   .  1
03 07 44.4 87.2 19 10 94 45 4 1015.0 9 9 X X X 09.0 09.2 04.1   .  08.5 16 01       0.06   .  1
03 10 44.5 86.6 20 12 91 45 4 1016.1 9 9 X X X 08.1 07.8 03.9   .  08.3 20 01       0.43   .  1
03 11 44.5 86.6 20 12 91 45 4 1016.1 9 9 X X X 08.0 07.6 04.0   .  08.0 20 01       0.52   .  1
03 13 44.6 86.3 19 12             .            08.3 07.7   .    .  07.4             0.68   .  1
03 13 42.4 87.0 22 11 98 C1 1 1018.6 1 1 0 4 0 12.5 10.6 07.2   .  08.6 22 01       1.19 1.27 2
03 14 44.6 86.3 18 14 95 43 4 1016.1 9 9 X X X 09.2 08.8 06.5   .  07.4 18 02       0.96   .  1
03 07 43.9 86.6 16 11             .            10.2 09.5   .    .  09.6             0.26   .  1
04 11 43.8 87.0 18 06             .            10.0 09.0   .    .  08.1             0.84   .  1
04 11 42.4 86.5 16 14 98 02 0 1016.5 1 0 0 0 1 16.6 14.7 10.7   .  11.2 17 00 18 01 1.13   .  2
04 13 42.2 86.6 17 07 98 03 1 1016.5 8 0 0 0 7 21.1 18.0 11.9   .  12.2 17 00 18 00 1.21 1.27 2
04 13 43.5 86.8 16 11 96 10 4 1016.5 7         10.3   .  06.5   .  09.2 18 02       1.04   .  1
04 15 42.0 86.7 18 09 98 01 1 1015.0 3 3 0 4 9 26.1 21.4 14.5   .  12.7 18 00       1.27 0.92 2
06 07 41.8 86.7 21 18             .            19.6 19.0 14.5   .  15.2             0.05   .  2
06 11 42.0 87.1 22 08             .            17.5 17.3 13.0   .  14.5             1.01   .  2
06 13 41.8 87.1 21 10             .            19.3 18.7 14.4   .  14.0             0.74 0.78 2
06 14 41.7 87.2 23 10             .            20.0 17.5 15.5   .  14.6             0.80 0.96 2
06 15 41.6 87.3 24 11             .            23.4 20.8 15.6   .  13.5             0.45 0.42 2
06 17 41.8 87.4 15 13             .            22.2 20.7 15.4   .  11.3             0.66 0.54 2
06 19 41.9 87.3 28 04             .            18.9 18.4 15.4   .  12.8             0.07 0.05 2
07 07 42.3 87.7 26 08             .            14.2 13.8 12.4   .  10.1             0.30 0.24 2
07 09 42.3 87.5 26 08             .            15.4 15.1 13.5   .  12.5             0.80 0.80 2
07 13 42.3 87.0 18 09             .            14.2 13.0 09.4   .  09.4             1.30 1.29 2
09 07 42.9 86.2 07 16             .            10.7 11.3   .    .  08.9             0.03   .  1
09 13 42.8 86.2 07 14             .            11.8 11.8   .    .  10.8             0.18   .  1
10 07 42.9 86.4 03 07             .            09.6 09.5   .    .  07.9             0.31   .  1
10 13 42.8 86.6 33 07             .            10.0 09.8   .    .  04.9             1.30   .  1
10 19 42.9 86.4 32 10 98 02 0 1020.8 1         10.6 10.6 09.2   .  04.7 33 01       0.19   .  1
11 13 43.3 87.1 16 12 98 03 0 1018.5 4 0 0 0     .    .    .    .    .  17 01        .     .  1
11 19 43.2 86.7 08 09 98 02 2 1016.2 7 3   0     .    .    .    .    .  00 00        .     .  1
12 20 43.1 86.3 00 00 98 02 2 1014.1 7 0 0 7 9 19.1 17.5 11.8   .  16.3 00 00 23 00 0.03   .  2
13 01 43.8 86.5 19 10 90 47 4 1014.0 9 9 X X X 11.1 10.2 07.5   .  09.6 00 00       0.00   .  2
14 13 44.8 86.1 20 14 98 02 0 1009.4 4   1 7 8 10.9 11.3 08.9   .  09.2 20 01       1.22   .  2
15 07 45.2 86.0 36 08 97 02 1 1011.6 6   8 7 1 09.5 09.8 09.2   .    .  36 00 25 01 0.16   .  2
15 12 45.2 85.9 26 07 98 01 0 1011.7 3   8 0 1 07.6 07.4 06.2   .  07.4 24 02       1.24   .  2
16 07 45.3 85.8 36 04 96 02 0 1012.3 1 0 0 0 1 08.1 06.0 06.2   .  07.4 36 00 33 01  .     .  2
16 14 45.2 85.8 28 12 99 02 0 1013.1 1 0 0 0 1 09.4 09.4 08.1   .  09.0 27 02        .     .  2
19 11 45.4 85.4 15 08 98 03 0 1018.1 2 0 0 0 8 13.6 13.2 11.2   .  11.1 15 01       1.06   .  2
20 13 45.4 85.9 26 10 98 02 2 1015.4 5   8 7 6 11.5 11.2 08.6   .  08.4 26 00 24 03 1.34   .  2
20 22 45.5 85.8 14 12 99 01 1 1019.5 1 1 6 0 0 14.7 11.9 10.6   .  11.1 00 00       0.00   .  2
20 07 43.1 86.4 20 11             .            16.1 15.6   .    .  11.6             0.16   .  1
20 13 43.1 86.7 19 11             .            15.4 14.6   .    .  12.3             1.24   .  1
21 15 45.1 86.1 36 10 97 03 1 1021.7 7   8 2 7 13.7 13.7 09.1   .  11.4 01 01       0.91   .  2
21 07 45.4 85.8 03 10 98 02 0 1023.3 2   8 2 8 13.2 13.7 11.2   .  11.3 03 01       0.38   .  2
21 07 43.4 86.5 26 09             .            21.3 17.1   .    .  14.9             0.28   .  1
21 10 43.5 86.7 15 06             .            20.8 17.5   .    .  15.0             0.78   .  1
21 13 43.6 86.7 20 10 97 05 2 1024.5 7 0 0 0   17.6 15.2 11.8   .  15.8 20 00       0.89   .  1
21 16 43.8 86.6 16 04             .            15.2 14.0   .    .  12.5             0.83   .  1
22 07 44.0 86.6 17 10 96 05 0 1023.1 1 0 0 0   14.1 13.0 10.8   .  11.3 17 00       0.27   .  1
22 10 44.1 87.0 19 09 96 05 0 1022.9 0 0 0 0 0 17.4 16.0 13.2   .  12.7 19 00       0.90   .  1
22 16 44.2 87.2 17 12 96 05 0 1020.3 C 0 0 0 0 16.8 16.3 14.5   .  12.1 17 01       0.85   .  1
23 07 44.0 87.4 18 07 96 05 4 1019.0 0 0 0 0 0 16.9   .  15.2   .  16.3 18 00        .     .  1
23 13 44.0 87.2 21 06             .            17.4 16.9   .    .  13.8             1.11   .  1
23 16 44.1 87.1 17 12 95 05 4 1016.9 0 0 0 0 0 17.5 17.1 15.5   .  13.6 18 01       0.76   .  1
23 19 44.6 86.2 17 02 96 10 4 4014.7 9 9 X X X 16.5 16.3 15.3   .  12.9 18 01       0.17   .  2
24 01 43.9 86.5 20 03             .            15.7 15.4 14.5   .  12.9             0.00   .  2
24 07 43.1 86.3                   .            22.3 21.9 17.5   .  15.7             0.25   .  2
24 07 44.0 87.4 20 08 95 05 5 1017.9 C 0 0 0 0 16.9 16.4 15.2   .  13.3 20 00       0.21   .  1
24 10 43.7 86.8 18 10 95 05 0 1018.1 C 0 0 0 0 17.5 16.7 14.2   .  12.7 19 00       0.87   .  1
24 13 43.5 86.6 15 10 95 05 0 1013.9 0 0 0 0 0 17.8 17.2 14.1   .  12.9 15 01       1.13   .  1
27 07 42.9 86.2 07 09 98 02 2 1021.9 8 4 X X X 19.6 19.6 22.2   .  14.6 08 00       0.11   .  1
27 08 42.8 86.3 09 07             .            20.8 20.7   .    .  15.0             0.21   .  1
27 09 42.8 86.4 09 07 98 02 2 1022.0 8 4 X X X 20.0 19.6 19.8   .  15.0 00 00       0.37   .  1
27 12 42.8 86.9 09 08             .            20.0 19.3   .    .  16.2             0.35   .  1
27 13 42.8 87.1 10 06 97 01 2 1021.0 6 0 0 0   19.8 19.8 19.1   .  15.9 00 00       1.20   .  1
27 13 42.8 86.2 36 08 98 02 2 1019.8 7 7 6 4 X 22.9 21.4 20.4   .  16.4 36 00        .     .  2
28 07 43.1 87.8 35 09 96 21 2 1017.2 8 8   X X 17.0 17.0 18.2   .  14.0 35 00       0.05   .  1
28 11 42.0 86.7 25 02 98 02 2 1015.7 8 8 4 2 X 20.6 15.0 21.4   .  18.5 25 01       0.13   .  2
28 13 42.0 87.1                   .            20.0 20.0 21.2   .  17.5             0.27   .  2
28 13 44.1 87.3 18 09 98 02 2 1017.5 7 7   0 0 17.3 17.0 16.8   .  13.4 17 00       0.69   .  1
28 14 42.0 87.1 05 09             .            21.1 21.1 21.4   .  17.5             0.60   .  2
28 15 44.4 87.1 22 06             .            17.8 17.5   .    .  13.8             1.06   .  1
29 07 44.4 87.2 24 08 94 46 4 1016.1 0 0 0 0 0 16.4 15.9 14.8   .  13.7 18 00       0.25   .  1
29 07 41.8 87.5 30 08 96 02 0 1016.2 2 2 0 2 0 21.3 21.2 20.6   .  18.0 30 01       0.20   .  2
29 11 44.5 86.6 26 06             .            17.5 17.3   .    .  15.0             1.03   .  1
29 13 44.6 86.3 26 08             .            17.3 16.3   .    .  15.0             1.13   .  1
29 13 41.9 86.9 31 09 98 02 0 1016.8 2 2 4 0 0 21.3 21.3 23.2   .  18.7 31 00       1.20   .  2
30 07 43.6 86.5 09 04 98 02 0 1019.0 1 0 0 0   20.9 20.7 20.9   .  13.4 00 00       0.28   .  1
30 09 42.4 86.3 22 04 96 02 0 1017.2 1 0 0 0   21.3 21.3 21.1   .  16.3 22 00       0.88   .  2
30 13 42.2 86.4 25 01             .            23.5 23.2 22.6   .  17.9             1.31   .  2
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TIMES LOCATIONS WINDS WEATHER PRESSR OKT CLOUD TEMPERATURES (DEGREES C) WAVES SWELL RADIATION V
DY HR LATD LONG DD FF VV WW W PPPPPP N A L M H AIRM AIRB WATI WATS TDPT DD HH DD HH SOLR NETR V

                                   JULY 1966

01 01 42.9 86.3 06 07             .            22.4 22.3   .    .  15.0             0.00  .   1
01 07 42.2 87.0 05 07             .  0         22.3 22.2   .    .  16.8             0.22  .   1
01 13 42.0 86.5                   .            26.7 25.0 22.6   .  20.0             1.29  .   2
01 19 42.9 86.3 18 06 97 00 0 1016.3 0 0 0 0 0 26.4 24.0 23.9   .  18.8 18 00       0.20  .   2
09 07 43.0 86.2 34 14 98 02 0 1007.7 2   4 0 1 20.4 20.5 22.4   .  15.0 34 03       0.00  .   2
20 13 43.4 86.4 21 13 98 02 0 1021.8 1 1 0 0 1 14.9 15.0 06.5   .  10.4 32 00       1.35  .   2
20 19 44.2 86.4 31 07 98 02 0 1020.2 0 0 0 0 0 18.9 18.7   .    .    .  33 00       0.21  .   2
21 01 44.9 86.0 01 09             .            18.1 18.1 14.6   .  19.1             0.00  .   2
21 14 44.9 86.0 26 13 99 02 0 1020.2 1 1 0 0 1 18.7 18.7 19.8   .  10.0 32 01        .    .   2
22 07 45.3 85.2 22 13 98 02 2 1019.0 6   5 2 7 17.5 17.5 19.8   .  13.1 27 01        .    .   2
21 19 45.3 85.3 25 09 99 02 0 1018.2 1 1 0 0 7 20.5 20.4 20.0   .  12.3 30 01       0.28  .   2
23 15 45.3 85.3 26 07 98 03 1 1018.0 5   2 7 7 20.8 20.8 19.7   .    .  26 00       0.61  .   2
24 10 45.4 85.2 21 12 97 02 2 1018.9 6   5 4   20.3 20.3 19.6   .  17.9 25 01       0.55  .   2
25 10 45.5 85.4 21 14 97 02 1 1017.7 4   0 7 9 21.3 21.4 20.2   .  19.5 22 03       0.75  .   2
26 11 45.6 85.4 10 13 99 02 2 1017.4 6   8 7 9 19.5 19.6 20.1   .    .  09 02       1.77  .   2
27 16 45.6 85.4 34 04 98 02 2 1008.8 8 8 5 X X 22.7 21.4 21.4   .  17.8 34 00       0.40  .   2
28 08 45.4 85.1 01 01 97 02 2 1008.5 8 8 5 X X 19.6 19.8 20.5   .  17.6 00 00        .    .   2
28 16 45.6 85.7 30 19 98 02 0 1009.0 2 2 4 0 9 21.3 21.3 20.6   .    .  34 03       0.85  .   2
29 14 45.6 85.6 25 04 99 02 0 1017.4 2   1 2 0 19.4 19.5 21.0   .    .  25 00       0.09  .   2

                                  AUGUST 1966

03 10 45.3 85.3 27 08 98 02 0 1017.8 1 1 1 0 0 18.3 18.6 19.9   .  10.7 27 01       1.01  .   2
03 18 45.6 85.4 21 14 99 02 0 1014.1 3   5 7 9 20.2 20.2 20.0   .    .  21 01        .    .   2
04 17 45.7 85.3 22 10 98 02 2 1013.6 6   4 7 1 21.4 21.2 20.4   .  18.7 22 00       0.23  .   2
05 07 45.7 85.4 32 10 97 02 2 1014.8 8   4 7 8 19.6 19.5 18.1   .  17.5 32 00       0.00  .   2
05 15 45.7 85.1 20 10 98 01 2 1014.3 5   4 7 9 20.1 20.2 19.9   .  17.7 20 00       1.01  .   2
06 12 45.7 85.7 23 09 96 03 1 1012.3 8   4 7 X 19.8 19.9 19.7   .  18.7 23 00        .    .   2
06 19 42.4 86.8 18 08             .            22.7 22.8 22.4   .  18.1             0.12  .   1
07 16 45.5 85.4 02 11 96 44 4 1008.9 9 9 X X X 21.1 21.1 20.2   .  19.8 02 02       0.35  .   2
08 07 45.2 85.4 16 14 96 01 1 1007.7 2 2 4 0 0 20.1 20.1 19.8   .  16.6 18 03       0.00  .   2
09 07 42.9 86.2 34 08 98 01 0 1014.9 4 0 0 0 4 18.0 18.1 20.2   .  13.2 30 03       0.20  .   1
09 11 42.8 86.6 31 01             .            18.5 18.4 20.1   .  10.8             1.14  .   1
09 13 42.8 86.9 18 05             .            19.0 19.0 20.9   .  10.4             1.19  .   1
10 07 42.7 87.5 09 02             .            20.0 19.8 21.5   .  15.0             0.07  .   1
10 10 42.8 86.9 29 05             .            21.2 20.7 20.5   .  16.8             0.40  .   1
10 13 42.8 86.4 20 08 97 02 2 1014.3 8 8   0 0 19.4 19.3 19.1   .  14.5 18 01       0.28  .   1
10 14 42.8 86.3 21 07 97 02 2 1014.0 8 8   0 0   .  18.8 19.1   .  16.8 18 01        .    .   1
11 01 44.0 86.5 01 08             .            16.9 17.0 18.8   .    .              0.00  .   2
11 07 43.3 86.4 01 09             .            16.5 16.8 19.5   .    .               .    .   2
11 07 43.1 86.3 34 06 98 02 2 1012.1 8       X 17.9 18.0 19.8   .  12.9 34 01       0.07  .   1
11 08 43.2 86.3 36 05             .            17.3 17.3 19.4   .  12.2             0.16  .   1
11 13 43.9 86.5 34 09 98 02 0 1013.2 7       X 17.0 17.0 18.9   .  11.3 34 01       1.39  .   1
12 07 44.7 86.2 32 13 99 00 0 1019.1 0 0 0 0 0 17.0 17.1 18.5   .  09.9 34 02       0.23  .   1
12 13 45.5 85.3 30 08 99 02 0 1021.2 1 1 1 0 0 17.3 17.4 20.4   .  07.6 33 02       1.27  .   1
19 11 43.0 86.5                   .            17.8 17.5 18.4   .  10.0             1.02  .   2
19 13 43.0 86.3 11 09             .            20.4 20.4 19.8   .  10.0             1.18  .   2
22 07 45.2 85.4 09 10 95 61 4 1011.0 9 9 X X X 15.5 15.5 18.2   .  11.6 09 00       0.02  .   1
22 10 44.9 86.0 19 10 95 05 4 1010.8 9 9 X X X 16.2 16.0 16.1   .  12.7 19 00       0.10  .   1
22 11 44.9 86.1 23 10 97 05 4 1010.9 9 9 X X X 16.8 16.8 16.8   .  14.2 23 00       0.30  .   1
22 13 44.6 86.3 27 14 98 02 2 1011.1 8 8   X X 18.5 18.4 18.3   .  12.8 27 02       0.23  .   1
22 19 43.6 86.5 29 18 98 01 1 1014.3 2 1       18.8 18.8 17.4   .  10.5 27 06       0.10  .   1
29 07 42.9 86.2 19 08 97 05 2 1017.8 5 0 0 0 5 21.8 21.4 20.6   .  15.0 20 01       0.11  .   1
29 08 42.8 86.3 19 07             .            21.2 21.1 20.8   .  15.0             0.35  .   1
29 09 42.8 86.4 19 08             .            21.3 21.2 20.2   .  15.0             0.53  .   1
29 12 42.8 86.9 19 10             .            21.5 21.4 21.5   .  15.7             1.05  .   1
29 13 42.8 87.1 18 12 96 05 4 1018.0 0 0 0 0 0 22.2 22.1 21.3   .  14.3             1.08  .   1
29 13 42.9 86.2 18 10 96 00 0 1017.5 0 0 0 0 0 21.4 21.4 20.6   .  18.6 19 01       1.01  .   2
29 19 42.1 86.4 14 06             .            26.6 25.9 22.8   .  16.7             0.00  .   2
30 07 42.1 86.6 22 10             .            22.0 22.0 21.5   .  17.6             0.00  .   2
30 07 43.1 87.8 25 10 97 05 0 1018.2 3 3   0 0 21.7 21.5 20.3   .  13.6 25 00       0.05  .   1
30 08 42.0 86.7 24 09             .            22.1 22.1 21.5   .  18.3             0.00  .   2
30 13 42.0 87.1 16 10 96 10 4 1018.8 9 9 X X X 24.2 23.9 22.3   .  19.1 16 00       1.04  .   2
30 13 44.1 87.3 26 04 94 05 4 1019.0 6 6   0 0 20.3 20.2 20.6   .  14.8 36 00       0.75  .   1
30 15 44.4 87.1 05 08             .            20.0 20.0 20.8   .  13.1             0.91  .   1
30 16 41.8 87.4 13 11 96 10 4 1016.8 9 9 X X X 26.3 25.4 22.5   .  19.3 13 00       0.43  .   2
31 07 44.4 87.2 03 12 97 02 2 1020.2 7 7   0 0 19.2 19.7 20.5   .  14.7 03 01       0.08  .   1
31 09 41.7 87.3 21 09 95 45 4 1019.2 9 9 X X X 23.6 23.5 22.0   .  18.8 00 00       0.45  .   2
31 10 41.8 87.3 21 09 95 45 4 1019.3 9 9 X X X 24.9 24.5 22.5   .  19.5 21 00       0.45  .   2
31 13 44.6 86.3 18 09             .            18.2 18.2 20.3   .    .              0.82  .   1
31 13 41.7 87.2 09 04 95 45 4 1018.2 9 9 X X X 26.1 25.5 23.4   .  18.7 09 00       0.82  .   2
```

| TIMES | | LOCATIONS | | WINDS | | WEATHER | | | PRESSR | CKT | CLOUD | | | | TEMPERATURES (DEGREES C) | | | | | WAVES | | SWELL | | RADIATION | | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DY | HR | LATD | LONG | DD | FF | VV | Ww | W | PPPPPP | N | A | L | M | H | AIRM | AIRB | WATI | WATS | TDPT | DD | HH | DD | HH | SOLR | NETR | V |
| SEPTEMBER 1966 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 01 | 07 | 41.7 | 87.0 | 16 | 09 | 96 | 43 | 4 | 1017.3 | 9 | 9 | X | X | X | 23.0 | 22.8 | 22.9 | . | 18.9 | 16 | 00 | | | 0.00 | . | 2 |
| 01 | 07 | 43.8 | 86.5 | 15 | 05 | 96 | 01 | 0 | 1017.3 | 1 | 1 | 0 | | 0 | 20.3 | 20.3 | 21.0 | . | 15.0 | 15 | 00 | | | 0.08 | . | 1 |
| 01 | 10 | 41.8 | 86.8 | 22 | 05 | 96 | 45 | 4 | 1016.8 | 9 | 9 | X | X | X | 22.8 | 22.9 | 22.9 | . | 18.6 | 22 | 00 | | | 0.63 | . | 2 |
| 01 | 13 | 41.9 | 86.7 | 27 | 02 | | | | . | | | | | | 24.8 | 24.6 | 23.6 | . | 20.1 | | | | | 0.94 | . | 2 |
| 17 | 07 | 43.0 | 86.3 | 15 | 02 | | | | . | | | | | | 18.0 | 17.9 | 18.3 | . | 07.9 | | | | | 0.09 | . | 1 |
| 18 | 07 | 43.0 | 87.6 | 09 | 04 | | | | . | | | | | | 18.1 | 18.1 | 19.2 | . | 07.7 | | | | | 0.03 | . | 1 |
| 18 | 08 | 43.0 | 87.4 | 09 | 04 | | | | . | | | | | | 17.7 | 17.9 | 20.3 | . | 07.0 | | | | | 0.12 | . | 1 |
| 18 | 10 | 43.0 | 87.4 | 05 | 02 | | | | . | | | | | | 17.5 | 17.5 | 18.7 | . | 08.0 | | | | | 0.39 | . | 1 |
| 18 | 13 | 43.0 | 86.9 | 35 | 01 | | | | . | | | | | | 17.7 | 17.7 | 18.9 | . | 08.2 | | | | | 0.97 | . | 1 |
| 19 | 07 | 42.9 | 86.3 | 07 | 13 | 97 | 02 | 0 | 1019.6 | 3 | 1 | 0 | | | 14.1 | 14.2 | 17.0 | . | 05.7 | 06 | 01 | | | 0.05 | . | 2 |
| 19 | 11 | 42.6 | 86.9 | 06 | 10 | | | | . | | | | | | 17.6 | 17.6 | 19.0 | . | 08.2 | | | | | 0.37 | . | 1 |
| 19 | 13 | 42.7 | 87.0 | 04 | 15 | 97 | 02 | 2 | 1018.2 | 8 | 0 | 0 | 0 | | 18.8 | 18.8 | 18.5 | . | 08.8 | 04 | 04 | | | 0.42 | . | 1 |
| 19 | 13 | 41.9 | 86.5 | 06 | 10 | 96 | 02 | 2 | 1014.7 | 8 | 8 | 6 | X | X | 21.7 | 21.5 | 18.4 | . | 09.3 | 04 | 02 | | | . | . | 2 |
| 19 | 14 | 42.7 | 87.0 | 02 | 14 | 97 | 02 | 2 | 1018.1 | 8 | 0 | 0 | 0 | | 18.8 | 18.8 | 19.4 | . | 09.6 | 04 | 03 | | | 0.46 | . | 1 |
| 20 | 13 | 43.6 | 86.7 | 36 | 16 | 98 | 02 | 2 | 1018.2 | 7 | 0 | 0 | 0 | | 16.0 | 15.9 | 15.2 | . | 07.7 | 36 | 03 | | | 0.70 | . | 1 |
| 20 | 15 | 43.9 | 86.8 | 36 | 19 | 98 | 02 | 2 | 1017.6 | 7 | 0 | 0 | 0 | | 16.7 | 16.7 | 17.0 | . | 09.2 | 01 | 05 | | | 0.47 | . | 1 |
| 21 | 07 | 44.0 | 86.6 | 01 | 08 | 97 | 05 | 2 | 1015.9 | 8 | 8 | | X | X | 13.3 | 13.1 | 12.8 | . | 06.8 | 01 | 01 | | | 0.02 | . | 1 |
| 21 | 08 | 44.1 | 86.7 | 04 | 11 | 97 | 02 | 2 | 1015.9 | 8 | 8 | | X | X | 15.0 | 15.1 | 16.5 | . | 07.3 | 03 | 02 | | | 0.12 | . | 1 |
| 21 | 10 | 44.3 | 86.6 | 06 | 04 | 97 | 02 | 2 | 1015.0 | 8 | 8 | | X | X | 15.0 | 15.0 | 17.9 | . | 08.1 | 06 | 00 | 02 | 01 | 0.40 | . | 1 |
| 21 | 13 | 44.4 | 86.7 | 33 | 02 | 97 | 02 | 2 | 1013.8 | 8 | 0 | 0 | 0 | | 16.3 | 16.2 | 18.7 | . | 08.6 | 00 | 00 | | | 0.84 | . | 1 |
| 22 | 07 | 42.8 | 86.5 | 36 | 08 | 98 | 01 | 0 | 1008.8 | 2 | 1 | | | 0 | 12.9 | 12.5 | 11.4 | . | 06.3 | 36 | 00 | 35 | 04 | 0.03 | . | 1 |
| 25 | 19 | 42.5 | 86.3 | 36 | 13 | 98 | 02 | 0 | 1016.2 | 4 | | 1 | 2 | 0 | 13.8 | 13.3 | 17.0 | . | 04.4 | 36 | 03 | | | 0.00 | . | 2 |
| 26 | 07 | 42.9 | 86.2 | 08 | 11 | 97 | 02 | 2 | 1018.0 | 7 | 7 | | X | X | 07.4 | 07.4 | 16.5 | . | -1.1 | 08 | 00 | | | 0.04 | . | 1 |
| 26 | 08 | 42.8 | 86.2 | 12 | 08 | | | | . | | | | | | 08.1 | 08.1 | 16.8 | . | 00.5 | | | | | 0.28 | . | 1 |
| 26 | 10 | 42.8 | 86.4 | 13 | 07 | | | | . | | | | | | 13.6 | 13.5 | 13.9 | . | 03.8 | | | | | 0.55 | . | 1 |
| 26 | 13 | 42.6 | 86.5 | 18 | 10 | 98 | 02 | 2 | 1018.1 | 6 | 6 | | 0 | 0 | 14.4 | 14.3 | 16.4 | . | 01.6 | 17 | 02 | | | 0.75 | . | 1 |
| 26 | 17 | 42.0 | 86.7 | 02 | 07 | | | | . | | | | | | 14.9 | 14.8 | 18.7 | . | 01.0 | | | | | 0.16 | . | 1 |
| 26 | 19 | 42.1 | 86.5 | 00 | 00 | | | | . | | | | | | 14.9 | 14.8 | 18.3 | . | 01.3 | | | | | 0.00 | . | 1 |
| 27 | 07 | 42.0 | 86.6 | 12 | 08 | 97 | 02 | 2 | 1013.0 | 8 | 6 | | X | X | 14.5 | 14.5 | 18.6 | . | 02.8 | 12 | 00 | | | 0.01 | . | 1 |
| 27 | 09 | 42.0 | 87.1 | 09 | 06 | | | | . | | | | | | 15.0 | 14.8 | 08.2 | . | 04.2 | | | | | 0.07 | . | 1 |
| 27 | 10 | 42.0 | 87.1 | 06 | 02 | | | | . | | | | | | 15.2 | 15.0 | 18.4 | . | 05.0 | | | | | 0.18 | . | 1 |
| 27 | 13 | 41.9 | 87.4 | 34 | 13 | 98 | 02 | 2 | 1013.8 | 8 | 8 | | X | X | 14.7 | 14.9 | 18.2 | . | 03.9 | 34 | 02 | | | 0.31 | . | 1 |
| 27 | 19 | 42.7 | 87.5 | 25 | 07 | 98 | 03 | 1 | 1012.9 | 5 | 5 | | 0 | 0 | 16.9 | 16.8 | 17.6 | . | 02.4 | 25 | 00 | | | 0.00 | . | 1 |
| 28 | 07 | 42.7 | 87.6 | 24 | 04 | 97 | 02 | 2 | 1010.9 | 6 | 6 | | 0 | 0 | 13.6 | 13.6 | 17.6 | . | 06.0 | 24 | 01 | | | 0.01 | . | 1 |
| 28 | 13 | 42.8 | 86.7 | 26 | 13 | 98 | 06 | 2 | 1008.0 | 8 | 8 | | X | X | 15.1 | 15.3 | 17.0 | . | 06.8 | 25 | 02 | | | 0.06 | . | 1 |
| 30 | 19 | 43.7 | 86.5 | 26 | 05 | 98 | 02 | 2 | 1009.8 | 7 | | 1 | 3 | X | 11.1 | 11.2 | 15.1 | . | 03.4 | XX | 01 | | | 0.00 | . | 2 |

```
TIMES LOCATIONS WINDS WEATHER PRESSR OKT CLOUD TEMPERATURES (DEGREES C) WAVES SWELL RADIATION V
DY HR LATD LONG DD FF VV WW W PPPPPP N A L M H AIRM AIRB WATI WATS TDPT DD HH DD HH SOLR NETR V

                                   OCTOBER 1966

01 07 44.0 86.5 33 12 98 01 1 1011.3 4 4 4 0 0 09.1 09.4 11.7    . 03.1 33 03        .     .   2
01 07 43.1 86.3 29 05 97 61 6 1013.2 7 7   X X 10.9 10.9 16.8    . 00.5 29 03       0.00  .   1
01 13 44.0 86.9 30 11 98 02 1 1014.9 5 4   0   10.2 10.2 15.1    . 00.0 30 02       0.93  .   1
01 13 44.7 87.2 34 07 98 01 1 1013.4 3 3 1 0 0 09.5 09.7 15.4    . 01.0 34 01        .     .   2
01 17 44.4 87.1 26 01                  .                 12.7 12.4 16.2    . -0.9             0.18  .   1
02 07 44.4 87.2 24 13 98 02 2 1015.0 7 7 0   X 11.4 11.6 16.0    . -0.1 24 00       0.00  .   1
02 10 44.5 86.6 24 11                  .                 12.9 13.1 14.1    . 01.4             0.61  .   1
02 13 44.6 86.4 21 10                  .                 11.1 10.7 08.9    . 02.3             0.44  .   1
06 13 44.2 86.9 21 16 98 00 0 1020.8 0 0 0 0 0 12.6 12.7 14.0    . 06.1 21 03       0.83 0.74 1
07 07 44.3 87.4 25 11 98 00 0 1013.5 0 0 0 0 0 12.6 12.1 09.5    . 05.8 25 00 18 04 0.00 -.07 1
08 13 43.9 87.5 16 14 98 01 0 1007.8 4 1 3 4 1 14.8 14.4 13.0    . 11.8 16 00 18 03 0.70 0.78 1
09 13 43.6 87.6 18 15 97 00 0 1003.1 0 0 0 0 0   .    .  13.9    .   .  16 01 16 03 0.65 0.75 1
12 07 43.8 87.6 29 06 98 00 0 1014.0 0 0 0 0 0 05.4 05.3 06.2    . 00.9 29 00 36 01 0.00 -.13 1
12 13 44.6 86.5 22 03 98 03 1 1014.2 5 0 0 0 8 09.2 09.1 13.3    . 02.3 22 00 36 01 0.73 0.65 1
12 18 45.0 85.9 36 06                  .                 09.2 09.2 12.8    . 03.1             0.00 -.15 1
12 19 44.9 86.0 06 08 98 01 1 1014.5 2 0 0 0 6 09.7 09.6 13.3    . 03.6 06 00       0.00 -.15 1
12 19 44.3 86.9 04 07 98 03 2 1014.0 8   0 5 8 08.5 08.6 10.0    . 05.9 04 00       0.00  .   2
13 01 43.5 86.5 10 07                  .                 11.0 11.1 11.4    . 05.6             0.00  .   2
13 07 44.4 86.3 10 19 98 60 6 1013.6 6 8 0 1 X 10.9 11.0 14.9    . 05.8 10 01       0.00 -.04 1
13 13 43.5 86.5 08 13 96 63 6 1011.2 8   7 2 X 11.1 11.1 14.0    . 09.6 08 00 12 02 0.07 0.06 1
17 19 42.5 86.2 29 02                  .                 08.6 08.8 14.7    . 01.7             0.00  .   2
18 07 42.4 86.4 22 09                  .                 07.9 08.2 14.0    . 04.4             0.00  .   2
18 07 43.3 86.4 15 08 98 02 2 1016.9 8 8 0 2 X 08.3 08.4 14.2    . 03.4 15 00 20 01 0.00  .   1
18 13 43.9 86.9 21 10 97 60 2 1014.8 6 8 5 X X 09.3 09.4 12.5    . 05.4 20 02       0.17  .   1
18 13 42.4 87.6 22 12                  .                 06.3 06.5 09.8    . 04.5             0.29  .   2
19 13 43.9 86.9                        .                 08.4 08.5 12.5    . 05.6             0.53  .   1
19 13 42.4 86.9 29 08 98 02 2 1013.1 7   4 4 X 08.8 09.0 13.4    . 05.9 29 00       0.21  .   2
20 13 43.9 87.6 16 14 98 00 0 1017.9 0 0 0 0 0 09.2 08.9 07.6 06.0 03.7 18 01       0.70 0.68 1
23 13 43.8 86.9 24 11                  .    1 1          08.4 08.6 10.6 10.0 00.7             0.49 0.31 1
24 13 44.6 86.3 29 11 98 02 0 1019.8 1 1 1 0 0 05.5 05.3 11.9 10.8 -3.0 29 03       0.76  .   1
24 13 41.9 86.5 33 10 97 02 0 1020.7 1 1 1 0 0 10.8 10.9 12.9    . 02.4 33 02       0.83  .   2
24 16 44.5 86.6 09 03                  .                 06.4 05.7 09.6 08.8 -2.9             0.19  .   1
24 18 44.5 86.9 09 07                  .                 05.6 05.4 08.2 07.4 -3.9             0.00  .   1
24 19 44.4 87.1 10 09                  .                 05.4 05.3 06.9 06.1 -2.5             0.00  .   1
25 07 44.4 87.2 30 05 98 00 0 1024.3 0 0 0 0 0 05.0 05.3 08.0 07.3 02.5 00 00       0.00  .   1
25 08 44.4 87.1 05 02 98 03 0 1025.3 1 0 0 0 1 08.3 07.1 07.6 06.7 -0.9 00 00       0.12  .   1
25 13 43.5 87.3 22 04 98 02 2 1024.6 7       X 07.7 07.6 11.6 11.1 -1.1 22 00       0.50  .   1
25 19 42.7 87.5 12 06                  .                 08.5 07.8 07.7 06.9 -0.7             0.00  .   1
26 07 42.5 87.7 25 06 96 00 0 1023.9 0 0 0 0 0 06.8 06.9 09.9 09.3 00.8 00 00       0.00  .   1
26 13 41.9 87.2 21 07 96 00 0 1024.9 0 0 0 0 0 10.7 10.8 13.8 13.4 01.2 21 00       0.78  .   1
26 13 42.0 86.5 25 05 98 00 0 1025.8 0 0 0 0 0 09.8 10.0 13.6    . 03.4 24 00       0.70  .   2
26 14 42.0 87.1 22 06 97 05 4 1023.9 0 0 0 0 0 11.6 11.6 13.6    . 01.4 22 00       0.65  .   1
26 16 42.0 86.7 25 04 97 00 0 1023.1 0 0 0 0 0 11.9 12.4 13.9 13.4 01.8 25 00       0.23  .   1
27 13 42.9 86.2 23 21 96 05 0 1017.1 0 0 0 0 0 12.8 12.8 13.5 13.1 06.6 22 06       0.67  .   1
30 07 42.9 86.2 14 12                  .                 01.4 02.1 12.4    . -1.6             0.00  .   2
```

| TIMES | | LOCATIONS | | WINDS | | WEATHER | | | PRESSR | OKT | CLOUD | | | | TEMPERATURES (DEGREES C) | | | | | WAVES | | SWELL | | RADIATION | | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DY | HR | LATD | LONG | DD | FF | VV | WW | W | PPPPPP | N | A | L | M | H | AIRM | AIRB | WATI | WATS | TDPT | DD | HH | DD | HH | SOLR | NETR | V |

NOVEMBER 1966

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 02 | 11 | 42.8 | 86.4 | 02 | 25 | 98 | 02 | 2 | 1018.5 | 8 | 0 | 0 | 0 | 7 | 01.3 | 01.7 | . | 11.2 | -6.6 | 02 | 01 | 36 | 05 | 0.33 | . | 1 |
| 02 | 13 | 43.0 | 86.2 | 01 | 06 | | | | . | | | | | | 01.1 | 01.3 | 11.0 | 11.6 | -6.7 | | | | | 0.33 | . | 1 |
| 05 | 13 | 43.9 | 86.8 | 16 | 18 | 98 | 02 | 2 | 1019.8 | 7 | 1 | 1 | 4 | 8 | 03.4 | 03.9 | 08.9 | 08.2 | 01.2 | 16 | 01 | 18 | 03 | 0.27 | . | 1 |
| 05 | 19 | 44.4 | 86.7 | 18 | 11 | 98 | 01 | 1 | 1020.0 | 0 | 0 | 0 | 0 | 0 | 03.9 | 03.9 | 06.9 | 06.2 | 00.1 | 18 | 01 | 18 | 04 | 0.00 | . | 1 |
| 06 | 07 | 44.6 | 86.3 | 16 | 11 | 98 | 02 | 2 | 1022.0 | 6 | 0 | 0 | 0 | 8 | 02.4 | 02.5 | 06.7 | 05.9 | 00.0 | 16 | 01 | 18 | 02 | 0.01 | . | 1 |
| 07 | 12 | 44.5 | 86.6 | 14 | 11 | | | | . | | | | | | 06.3 | 06.4 | 08.7 | 08.2 | 05.4 | | | | | 0.15 | . | 1 |
| 07 | 13 | 44.5 | 86.8 | 14 | 11 | 92 | 45 | 4 | 1008.3 | 9 | 9 | X | X | X | 07.4 | 07.4 | 08.0 | 07.5 | 05.9 | 14 | 01 | 18 | 04 | 0.10 | . | 1 |
| 07 | 16 | 44.4 | 87.1 | 16 | 14 | 93 | 45 | 4 | 1004.6 | 9 | 9 | X | X | X | 08.1 | 07.9 | 07.9 | 07.2 | 07.1 | 16 | 01 | 18 | 02 | 0.07 | . | 1 |
| 07 | 17 | 44.4 | 87.4 | 18 | 09 | 92 | 45 | 4 | 1004.4 | 9 | 9 | X | X | X | 08.6 | 08.6 | 08.7 | 07.9 | 07.6 | 19 | 01 | 18 | 02 | 0.01 | . | 1 |
| 07 | 19 | 44.1 | 87.5 | 17 | 03 | 96 | 42 | 4 | 1003.9 | 9 | 8 | 6 | X | X | 09.1 | 08.6 | 07.9 | 07.1 | 08.1 | 00 | 00 | 18 | 02 | 0.00 | | 1 |
| 08 | 07 | 43.9 | 87.6 | 34 | 10 | 98 | 02 | 2 | 1008.8 | 8 | 8 | 0 | 7 | X | 07.6 | 07.3 | 06.6 | 05.7 | 02.7 | 34 | 00 | 18 | 03 | 0.00 | -.04 | 1 |
| 08 | 13 | 43.1 | 87.4 | 02 | 14 | 98 | 02 | 2 | 1009.8 | 8 | 8 | 5 | X | X | 08.1 | 07.9 | 07.7 | 07.7 | 03.6 | 02 | 01 | | | 0.55 | 0.43 | 1 |
| 08 | 13 | 42.6 | 86.3 | 03 | 07 | 97 | 02 | 2 | 1009.2 | 8 | 8 | 6 | X | X | 08.8 | 09.0 | 10.2 | 10.2 | 06.5 | 03 | 00 | 34 | 03 | 0.08 | . | 2 |
| 08 | 15 | 42.7 | 87.4 | 03 | 10 | 98 | 02 | 2 | 1009.7 | 8 | 8 | 6 | X | X | 08.4 | 06.2 | 09.0 | 08.7 | 05.4 | 03 | 01 | | | 0.06 | 0.05 | 1 |
| 08 | 16 | 42.7 | 87.5 | 03 | 10 | 98 | 02 | 2 | 1009.8 | 8 | 8 | 6 | X | X | 07.9 | 07.8 | 08.8 | 08.0 | 06.7 | 03 | 01 | | | 0.02 | 0.00 | 1 |
| 09 | 07 | 42.7 | 87.6 | 06 | 10 | 92 | 45 | 4 | 1006.1 | 9 | 9 | X | X | X | 08.3 | 08.3 | 13.1 | . | 07.9 | 06 | 01 | 02 | 04 | 0.00 | . | 1 |
| 09 | 09 | 42.0 | 86.7 | 10 | 18 | 96 | 02 | 2 | 1005.7 | 8 | 8 | 5 | X | X | 13.3 | 13.3 | 10.6 | 10.6 | 11.7 | 10 | 01 | 36 | 02 | 0.02 | . | 2 |
| 09 | 13 | 41.9 | 87.3 | 21 | 11 | 97 | 02 | 2 | 1002.4 | 8 | 8 | 5 | X | X | 13.1 | 12.4 | 10.1 | 10.1 | 11.9 | 19 | 01 | 36 | 03 | 0.10 | . | 2 |
| 09 | 13 | 42.8 | 86.9 | 18 | 04 | | | | . | | | | | | 11.5 | 11.1 | 09.4 | . | 10.0 | | | | | 0.18 | . | 1 |
| 09 | 14 | 41.8 | 87.4 | 18 | 13 | | | | . | | | | | | 13.6 | 12.0 | 09.9 | 09.8 | 11.3 | | | | | 0.41 | . | 2 |
| 09 | 15 | 42.6 | 86.9 | 20 | 15 | 96 | 42 | 4 | 1001.5 | 8 | 8 | 0 | 7 | X | 12.4 | 12.1 | 10.7 | . | 11.1 | 20 | 01 | 18 | 03 | 0.10 | . | 1 |
| 09 | 18 | 42.8 | 86.4 | 28 | 08 | 92 | 47 | 4 | 1002.5 | 9 | 9 | X | X | X | 10.0 | 09.8 | 10.5 | . | 08.6 | 28 | 00 | 18 | 03 | 0.00 | . | 1 |
| 09 | 19 | 42.8 | 86.3 | 27 | 10 | 92 | 45 | 4 | 1002.5 | 9 | 9 | X | X | X | 10.3 | 10.1 | 10.6 | . | 09.2 | 27 | 01 | 18 | 02 | 0.00 | . | 1 |
| 10 | 13 | 41.8 | 87.5 | 30 | 10 | 97 | 02 | 2 | 1006.5 | 8 | 8 | 5 | X | X | 02.2 | 02.8 | 08.2 | 08.2 | -0.6 | 30 | 01 | | | 0.08 | . | 2 |
| 13 | 13 | 41.6 | 87.3 | 21 | 13 | 97 | 02 | 0 | 1028.2 | 2 | 2 | 4 | 0 | 1 | 07.1 | 07.3 | 08.6 | 08.6 | 00.6 | 21 | 01 | | | 0.62 | . | 2 |
| 13 | 19 | 41.9 | 86.7 | 19 | 10 | | | | . | | | | | | 08.2 | 08.4 | 10.1 | 10.2 | 01.3 | | | | | 0.00 | . | 2 |
| 14 | 01 | 42.6 | 86.2 | 21 | 16 | | | | . | | | | | | 08.6 | 08.8 | 09.3 | 09.5 | 02.9 | | | | | 0.00 | . | 2 |

# TEMPERATURE STRUCTURE OF LAKE MICHIGAN*

Vincent E. Noble

All of the bathythermograph data taken by the Great Lakes Research Division are in the process of being reduced and put onto punched cards for computer processing. The surface water temperature was read with an independent thermometer at the time of each BT cast. The BT slides were superimposed upon the appropriate calibration grid in a specially designed photographic enlarger carrier, and the position of the slide was adjusted with respect to the calibration grid, so that the projected image had the slide tracing adjusted to the correct surface temperature. The resulting enlarged image was printed on a 3 x 5-in. piece of No. 6 photographic paper. The temperature curves were read at each "significant" point, beginning with the surface temperature. "Significant" points were defined as those points that, when connected by straight-line segments, would produce an adequate synthesis of the temperature curve. The points were read to the nearest whole meter of depth and the nearest 0.1°C of temperature. Because of the varying shapes of the temperature curves, varying numbers of points were required for each of the BT casts. The data were punched onto IBM cards in a standard format for computer processing.

The following table describes the format used on the standard 80 column IBM card:

GLRD BATHYTHERMOGRAPH PUNCH CARD FORMAT

| Column | Character | Name | Description |
|---|---|---|---|
| 1 | Skip | | Blank column |
| 2-3 | C2 | Code | Description of card type. BT used for routine casts, TT used for special-purpose temperature transects |
| 4-8 | (I2,F3.1) | Lat | Latitude in degrees, minutes and tenths |
| 9-13 | (I2,F3.1) | Long | Longitude in degrees, minutes and tenths |
| 14 | Skip | | |
| 15-16 | I2 | Date | Day of month |
| 17-18 | C2 | Month | JA,FE,MA,AP,MY,JU,JL,AU,SP,OC,NO,DC |

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*Partially supported by NSF Atmospheric Sciences Section Grant GA-524.

| Column | Character | Name | Description |
|---|---|---|---|
| 19-20 | I2 | Year | |
| 21-24 | I4 | Time | EST written as 0001 to 2400 |
| 25 | Skip | | |
| 26-30 | (I4,C1) | BT slide No. | Four digit number, followed by one-character ship designator |
| 31-35 | (I4,C1) | BT serial No. | Instrument serial number (for designation of calibration grid) |
| 36 | (I1) | No. of cards | Indicator of the number of punch cards that are required to record the data from an individual BT cast |
| 37 | I1 | Card No. | Serial number of individual card within set for an individual BT cast |
| 38 | Skip | | |
| 39-40 | 7(I3,F3.1) | 7(Depth, T(Depth)) | Seven paired groupings of depths read to the nearest meter, with the corresponding temperatures read to the nearest tenth degree Centigrade. The data points are sequential from the surface readings to the bottom reading for the individual BT cast. |

The first 35 columns of cast and card identification were repeated on each card punched to provide adequate redundant information for self-protection in the event of cataclysmic occurrences such as dropping a deck of data cards, and for ease in interpretation of the data format when exchanging data with other agencies.

Samples of BT cards are shown below, the first cast 0619S, required only one card to record the data, while the second cast 0620S, required two cards:

```
BT4200787170  08JU630700  0619S5005B11  0001630051620071060120670170520430460540044
BT4205987170  08JU630835  0620S5005B21  0001480051470071060080860100760150580210052
BT4205987170  08JU630835  0620S5005B22  033048054046
```

The following program was developed to compute the average temperature for each 10-m layer of water depth, for each one-degree square of latitude and longitude, for each month of the year:

```
              TEMPERATURE AVERAGES
               INTEGER IX,LT,LN,ID,DEPTH,I,J,K,M,N,DUMP,LAT,LON, YR,SLNO,C,
             1    LSLN, BAD, LCONC, P
              DIMENSION (A,IX)((0...300)*12),S(999), P(28), T(28)
              VECTOR VALUES MONTH(1)= $JA$,$FE$,$MA$,$AP$,$MY$,$JU$,$JL$,$AU$,$SP$,
             1         $OC$,$NO$,$DC$
              SETEOF. (TAPE)
              REWIND TAPE 2
              LSLN = 0
              BAD = 0
              LCONC = 0
    READ      READ FORMAT $T2,C2,T4,I2,T9,I2,T17,C2,T19,I2,T27,I3,T36,I1,I1,T39,
             1 7(I3,F3 )*$,ID,LT,LN,MONTH,YR,SLNO,J,C,(I=1,1,I.G.7,P(I),
             2  T(I))
              WHENEVER ID.NE.$BT$, TRANSFER TO READ
              WHENEVER J.L.C.OR.(C.E.1.AND.SLNO.E.LSLN),  BAD = 3
              WHENEVER C.G.1.AND.SLNO.NE.LSLN,  BAD = 3
              WHENEVER C.NE.LCONO+1
                   PRINT COMMENT $CARDS NOT IN ORDER$
                   BAD = 3
              OTHERWISE
                   LCONO = C
              END OF CONDITIONAL
              WHENEVER C.E.J, LCONO = C
              WHENEVER  BAD.E.3
                   PRINT RESULTS SLNO, MONTH,YR, J, C
                   BAD = 2
              END OF CONDITIONAL
              WHENEVER  J.GE.C,  LSLN = SLNO
              WRITE BCD TAPE 2, TEMP, ID,LT,LN,MONTH,YR,SLNO,J,(I=1,1,I.G.
             1  7,P(I),T(I))
              VECTOR VALUES TEMP = $S1,C2,I2,S3,I2,S6,C2,I2,S6,I3,S6,I1,(T39,7(I3,
             1 F3))*$
              TRANSFER TO READ
    TAPE      END OF FILE TAPE 2
              WHENEVER BAD.E.2, SYSTEM.
              REWIND TAPE 2
              SETEOF. (TRACK)
              THROUGH BETA, FOR LON=85,1, LON.G.87
              THROUGH BETA,FOR LAT=41,1, LAT.G.45
              ZERO. (A(0,1)...A(300,12), IX(0,1)...IX(300,12))
    ALPHA     ZERO. (S...S(300))
              ZERO. (P...P(28) ,  T...T(28))
              READ BCD TAPE 2, TEMPS, ID,LT,LN,MONTH,YR,SLNO,J,(I=1,1,I.G.
             1 7*J, P(I),T(I))
              VECTOR VALUES TEMPS = $S1,C2,I2,S3,I2,S6,C2,I2,S6,I3,S6,I1,(T39,
             1 7(I3,F3))*$
              (M=1,1,MONTH.E.MONTH(M).OR.M.E.13)
              WHENEVER M.E.13.OR.LT.NE.LAT.OR.LN.NE.LON.OR.ID.NE.$BT$,TRANSFER TO ALPHA
              (I=1,1,T(I).E.C, DEPTH=P(I),S(DEPTH)=T(I))
              (I=300,-1,S(I).NE.C.)
              N=I-10
              (I=I,-K,I.LE.1,(K=1,1,S(I-K).NE.O.),Q=(S(I-K)-S(I))/K,(J=1,1,
             1          J.E.K,S(I-J)=S(I)+(J*C)))
              (I=0,10,I.G.N,J=I/10,A(J,M)=(B=0.,K=0,1,K.E.10,B+S(I+K))
             1          /10.+A(J,M),IX(J,M)=IX(J,M)+1)
              TRANSFER TO ALPHA
    TRACK     REWIND TAPE 2
              PRINT FORMAT $1H1,T23,H*AVERAGE TEMPERATURE BY 10 METER LAYER*//T21,
             1 10HLATITUDE =I3,2H N, S2, 11HLONGITUDE =I3,2H W,S3,2H19I2*$,
             2    LAT,  LON,  YR
              PRINT FORMAT OUTPUT, (I=0,10,I.G.291,I,I+9,(J=1,1,J.E.13,A(I/10,J)/
             1          (10.*IX(I/10,J))))
              VECTOR VALUES OUTPUT=$9HCINTERVAL T15, H*JAN   FEB   MAR   APR   MAY
             1 JUN   JUL   AUG   SEP   OCT   NOV   DEC*/(/(10(S1,I3,3H - LI3
             2 ,T14,12(F4.1,S2)/))*$
              PRINT FORMAT $1H1,T23,H*NUMBER OF BT'S USED TO COMPUTE AVG TEMP*//T21,
             1 10HLATITUDE =I3,2H N,S2,11HLONGITUDE =I3,2H W,S3,2H19I2*$,
             2    LAT,  LON,  YR
              PRINT FORMAT NUMBER, (I=0,10, I.G.291, I, I+9, (J=1, 1, J.E.
             1 13, IX(I/10,J)))
              VECTOR VALUES NUMBER=$9HCINTERVAL T15, H*JAN   FEB   MAR   APR   MAY
             1 JUN   JUL   AUG   SEP   OCT   NOV   DEC*/(/(10(S1,I3,3H - LI3
             2   ,T14, 12(I4,S2)/))*$
    BETA       CONTINUE
              END OF PROGRAM
```

In the execution of this program, only the regular BT casts (coded BT) were used for the computation of the average temperatures. The BT casts were generally taken at two-week or one-month intervals when the regular biological reference stations were occupied. There were generally 300 to 500 casts designated as "BT" taken throughout the course of the season. The special-purpose temperature-transect casts, designated as "TT," were not included in the average temperature computation because of the weighting effect they would have upon the averages. During a temperature transect, as many as 50 casts would be made on a single day. As many as 300 "TT" casts can be expected in a given season.

Because of the spatial distribution of the BT casts, one-degree squares of latitude and longitude were determined to be the minimum area that would provide representative average values. The average temperature program, as written, does not include stations of less than 10 m total depth in the computation of average temperature. Further, because of the rate of change of temperature structure in the lake, and because of the temporal spacing of the BT casts, it was felt that the minimum time period for meaningful averaging of the temperature structure was one month.

The BT's are assigned to the one-degree latitude-longitude squares according to the whole degrees given in the station position. A BT cast taken at 44°37.5'N, 86°18.2'W would be averaged in the square designated by latitude 44°, longitude 86° (Fig. 1).

Examples of the winter thermal structure of the lake as shown by Heap and Noble (1966), of the several features of the surface temperature structure along the Milwaukee-Muskegon line as illustrated by Noble (1966a), and of the thermal-mechanical processes operative in the fall overturn of the lake (Noble 1966b), indicate that any estimates of the heat budget of the lake based upon temperature measurements may show wide differences with only slight changes in the time and place of measurement. Meaningful heat budget estimates are extremely difficult to obtain from single-point BT observations unless appropriate averaging methods are applied. These estimates are particularly sensitive to approximation errors during the transitional periods of spring warming and fall overturn.

The monthly average temperatures for each 10-m depth interval for each one-degree square of latitude and longitude are given in Tables 1-4 for the years 1963, 1964, 1965, 1966. These tables also include a count of the number of BT casts used to compute the temperature averages for each depth interval. The rate of decrease of number of BT casts used as the depth interval increases gives an indication of the number of deep and shallow BT's taken within the square within the month, the depths of the several casts, and an indication of the weighting of the shallow-water temperature averages as a result of near-shore effects during the spring and fall of the year.

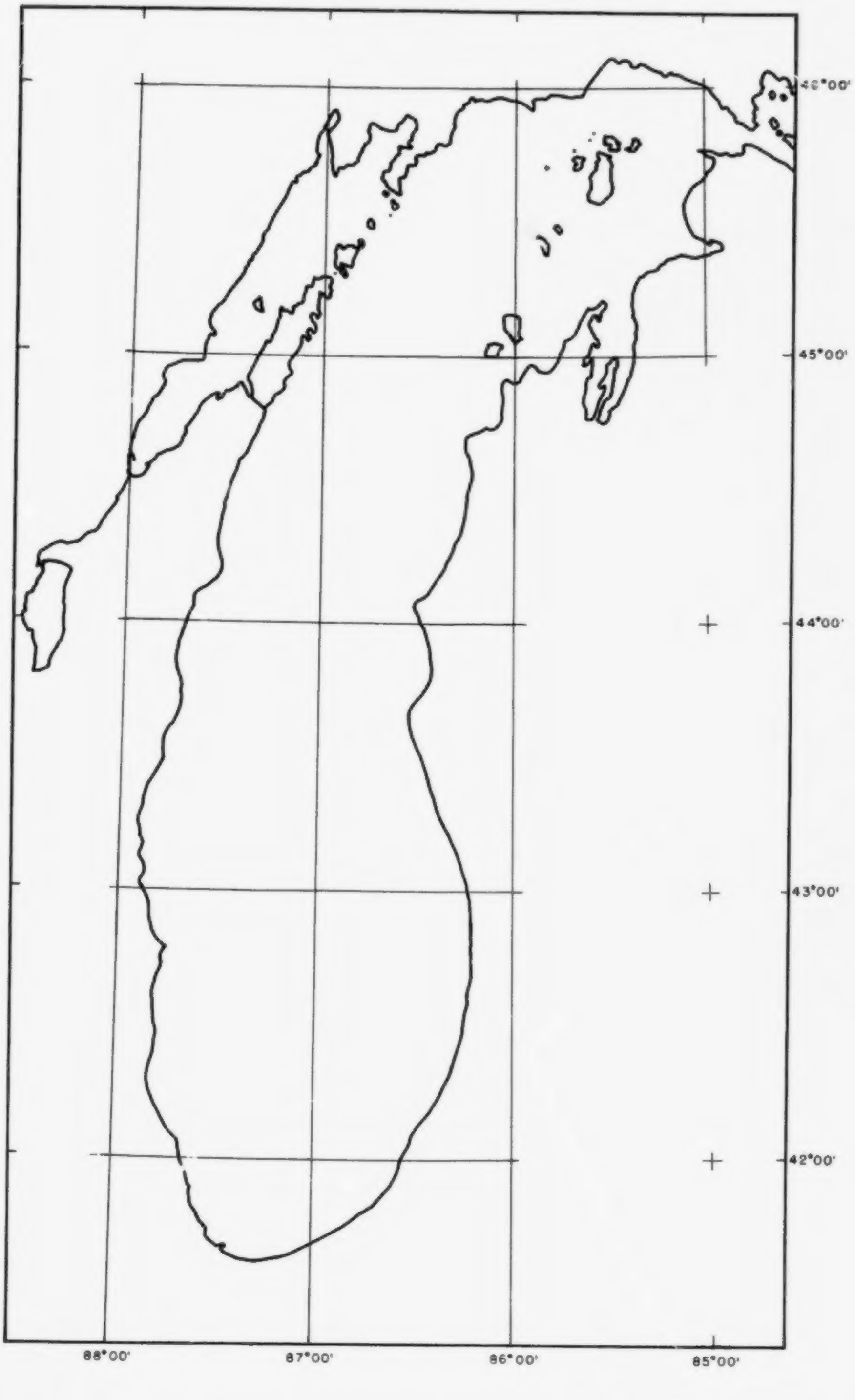
46°00'
45°00'
44°00'
43°00'
42°00'
88°00'
87°00'
86°00'
85°00'

FIG. 1. Lake Michigan showing latitude and longitude grid.

Two conspicuous features of the temperature structure of the lake as given by the following tables are that the "summer" period, when the thermocline exists, is only from the middle of June to about the middle of November, and that the "deep" water of the lake is at its warmest at the time of the deep fall mixing at the end of November or early December.

The four years of temperature data presented below form the beginning of a continuing program of documentation and study of the detailed temperature structure and thermal budget of Lake Michigan.

## REFERENCES

HEAP, JOHN A., and VINCENT E. NOBLE. 1966. Growth of ice on Lake Michigan. Univ. Michigan., Great Lakes Res. Div., Spec. Rept. No. 26, 94 p.

NOBLE, V. E. 1966a. Vertical current structure in the Great Lakes. Univ. Michigan, Great Lakes Res. Div., Spec. Rept. No. 27, 42 p.

__________. 1966b. Observations of the fall overturn of Lake Michigan. Limnol. Oceanog., 11(1966): 413-415.

# TABLE 1

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 45 N LONGITUDE = 85 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF PT'S USED TO COMPUTE AVG TEMP

LATITUDE = 45 N LONGITUDE = 85 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 41 N LONGITUDE = 86 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 17.0 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 16.9 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 12.4 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 6.5 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 5.0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.7 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF PT'S USED TO COMPUTE AVG TEMP

LATITUDE = 41 N LONGITUDE = 86 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 42 N LONGITUDE = 86 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | 2.0 | 3.5 | 6.9 | .0 | .0 | .0 | 16.3 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | 2.0 | 3.5 | 5.2 | .0 | .0 | .0 | 16.2 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | 2.0 | 3.5 | 5.0 | .0 | .0 | .0 | 15.4 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | 2.0 | 3.5 | 4.9 | .0 | .0 | .0 | 7.7 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | 2.0 | 3.5 | 4.9 | .0 | .0 | .0 | 4.9 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | 2.0 | 3.6 | 4.9 | .0 | .0 | .0 | 4.5 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | 2.0 | 3.6 | 4.8 | .0 | .0 | .0 | 4.6 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | 2.0 | 3.6 | 4.9 | .0 | .0 | .0 | 4.5 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | 2.1 | 3.6 | 4.8 | .0 | .0 | .0 | 4.4 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | 2.1 | 3.8 | 4.8 | .0 | .0 | .0 | 4.3 | .0 | .0 |
| 100 - 109 | .0 | .0 | .0 | 2.2 | 3.8 | 4.7 | .0 | .0 | .0 | 4.0 | .0 | .0 |
| 110 - 119 | .0 | .0 | .0 | 2.2 | 3.8 | 4.7 | .0 | .0 | .0 | 4.0 | .0 | .0 |
| 120 - 129 | .0 | .0 | .0 | 2.2 | 3.8 | 4.7 | .0 | .0 | .0 | 4.0 | .0 | .0 |
| 130 - 139 | .0 | .0 | .0 | 2.3 | 3.9 | 4.6 | .0 | .0 | .0 | 4.0 | .0 | .0 |
| 140 - 149 | .0 | .0 | .0 | 2.4 | 4.0 | 4.6 | .0 | .0 | .0 | 4.0 | .0 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF PT'S USED TO COMPUTE AVG TEMP

LATITUDE = 42 N LONGITUDE = 86 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 4 | 1 | 3 | 0 | 0 | 0 | 9 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 4 | 1 | 3 | 0 | 0 | 0 | 9 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 4 | 1 | 3 | 0 | 0 | 0 | 9 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 4 | 1 | 3 | 0 | 0 | 0 | 9 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 4 | 1 | 3 | 0 | 0 | 0 | 9 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 4 | 1 | 3 | 0 | 0 | 0 | 9 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 4 | 1 | 3 | 0 | 0 | 0 | 2 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 3 | 1 | 2 | 0 | 0 | 0 | 2 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 0 | 0 | 2 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 0 | 0 | 2 | 0 | 0 |
| 100 - 109 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 110 - 119 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 120 - 129 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 130 - 139 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 140 - 149 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 1 (Continued)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 43 N LONGITUDE = 86 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | 4.4 | .0 | .0 | .0 | .0 | 14.9 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | 4.4 | .0 | .0 | .0 | .0 | 14.9 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | 4.4 | .0 | .0 | .0 | .0 | 11.3 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | 4.5 | .0 | .0 | .0 | .0 | 4.6 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | 4.5 | .0 | .0 | .0 | .0 | 3.5 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 3.5 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 43 N LONGITUDE = 86 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 44 N LONGITUDE = 86 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 44 N LONGITUDE = 86 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 45 N LONGITUDE = 86 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 45 N LONGITUDE = 86 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## TABLE 1 (Continued)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 41 N  LONGITUDE = 87 W  1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | 2.9 | 5.4 | 17.0 | .0 | .0 | .0 | 17.2 | 12.4 | .0 |
| 10 - 19 | .0 | .0 | .0 | 3.2 | .0 | 8.8 | .0 | .0 | .0 | 16.7 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | 3.0 | .0 | .0 | .0 | .0 | .0 | 11.2 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | 2.4 | .0 | .0 | .0 | .0 | .0 | 5.7 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | 2.0 | .0 | .0 | .0 | .0 | .0 | 5.0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.7 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF PT'S USED TO COMPUTE AVG TEMP

LATITUDE = 41 N  LONGITUDE = 87 W  1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 7 | 1 | 2 | 0 | 0 | 0 | 7 | 1 | 0 |
| 10 - 19 | 0 | 0 | 0 | 6 | 0 | 1 | 0 | 0 | 0 | 4 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 42 N  LONGITUDE = 87 W  1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | 3.7 | 13.4 | .0 | .0 | .0 | 14.8 | 13.3 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | 3.7 | 6.2 | .0 | .0 | .0 | 16.7 | 13.2 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | 3.7 | 5.1 | .0 | .0 | .0 | 14.9 | 13.2 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | 3.7 | 4.8 | .0 | .0 | .0 | 7.5 | 11.9 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | 2.7 | 4.6 | .0 | .0 | .0 | 5.3 | 6.0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | 3.4 | .0 | .0 | .0 | .0 | 4.7 | 5.3 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | 3.4 | .0 | .0 | .0 | .0 | .0 | 5.3 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | 3.3 | .0 | .0 | .0 | .0 | .0 | 5.3 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | 3.3 | .0 | .0 | .0 | .0 | .0 | 5.2 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | 3.3 | .0 | .0 | .0 | .0 | .0 | 5.2 | .0 |

NUMBER OF PT'S USED TO COMPUTE AVG TEMP

LATITUDE = 42 N  LONGITUDE = 87 W  1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 5 | 2 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 5 | 2 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 5 | 2 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 5 | 2 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 5 | 2 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 2 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 43 N  LONGITUDE = 87 W  1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | 2.5 | .0 | .0 | .0 | .0 | .0 | .0 | 13.6 | .0 |
| 10 - 19 | .0 | .0 | .0 | 2.4 | .0 | .0 | .0 | .0 | .0 | .0 | 13.4 | .0 |
| 20 - 29 | .0 | .0 | .0 | 2.6 | .0 | .0 | .0 | .0 | .0 | .0 | 13.5 | .0 |
| 30 - 39 | .0 | .0 | .0 | 2.7 | .0 | .0 | .0 | .0 | .0 | .0 | 12.3 | .0 |
| 40 - 49 | .0 | .0 | .0 | 2.6 | .0 | .0 | .0 | .0 | .0 | .0 | 5.4 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 5.1 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.8 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.5 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.4 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.3 | .0 |
| 100 - 109 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.2 | .0 |
| 110 - 119 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.2 | .0 |
| 120 - 129 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.1 | .0 |
| 130 - 139 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.0 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | 0 | 0 | .0 | .0 | .0 | .0 |

NUMBER OF PT'S USED TO COMPUTE AVG TEMP

LATITUDE = 43 N  LONGITUDE = 87 W  1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 10 - 19 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 20 - 29 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 30 - 39 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 40 - 49 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 100 - 109 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 110 - 119 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 120 - 129 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 130 - 139 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## TABLE 1 (Concluded)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 44 N LONGITUDE = 87 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 44 N LONGITUDE = 87 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 45 N LONGITUDE = 87 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 45 N LONGITUDE = 87 W 1963

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 2

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 45 N LONGITUDE = 85 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 13.0 | 11.3 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 12.0 | 11.1 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 12.9 | 11.1 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 12.9 | 11.1 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 12.8 | 11.0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 12.8 | 10.8 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 11.8 | 10.4 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 10.6 | 9.1 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 8.9 | 7.8 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 8.2 | 7.3 | .0 |
| 100 - 109 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 7.3 | 7.0 | .0 |
| 110 - 119 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 6.8 | .0 |
| 120 - 129 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 130 - 139 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BTS USED TO COMPUTE AVG TEMP

LATITUDE = 45 N LONGITUDE = 85 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 |
| 100 - 109 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 110 - 119 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 120 - 129 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 130 - 139 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 41 N LONGITUDE = 86 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BTS USED TO COMPUTE AVG TEMP

LATITUDE = 41 N LONGITUDE = 86 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 2 (Continued)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 42 N LONGITUDE = 86 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | 4.4 | 6.4 | 13.6 | 17.8 | 15.2 | 17.5 | 14.0 | 11.6 | .0 |
| 10 - 19 | .0 | .0 | .0 | 3.6 | 5.0 | 11.2 | 13.4 | 18.4 | 17.1 | 13.6 | 11.4 | .0 |
| 20 - 29 | .0 | .0 | .0 | 3.8 | 4.7 | 8.0 | 8.9 | 13.3 | 15.0 | 13.1 | 11.5 | .0 |
| 30 - 39 | .0 | .0 | .0 | 3.5 | 4.6 | 5.4 | 6.3 | 5.7 | 10.0 | 13.1 | 11.8 | .0 |
| 40 - 49 | .0 | .0 | .0 | 3.5 | 4.5 | 5.0 | 4.4 | 4.4 | 6.4 | 6.5 | 10.2 | .0 |
| 50 - 59 | .0 | .0 | .0 | 3.4 | 4.1 | 4.9 | 4.3 | 4.4 | 5.7 | 4.1 | 5.9 | .0 |
| 60 - 69 | .0 | .0 | .0 | 3.4 | 4.1 | 4.7 | 4.7 | 4.0 | 4.7 | 4.8 | 5.3 | .0 |
| 70 - 79 | .0 | .0 | .0 | 3.1 | .0 | 4.5 | 4.1 | 4.0 | 4.6 | 4.5 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | 3.1 | .0 | 4.8 | 4.0 | 4.0 | 4.5 | 4.4 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | 3.1 | .0 | 4.8 | 4.0 | 4.0 | 4.5 | 4.4 | .0 | .0 |
| 100 - 109 | .0 | .0 | .0 | 3.1 | .0 | 4.7 | 3.9 | 4.0 | 4.5 | 4.1 | .0 | .0 |
| 110 - 119 | .0 | .0 | .0 | 3.3 | .0 | 4.7 | 3.8 | 4.0 | 4.2 | 4.1 | .0 | .0 |
| 120 - 129 | .0 | .0 | .0 | 3.3 | .0 | 4.6 | 3.7 | 4.0 | 4.2 | 4.1 | .0 | .0 |
| 130 - 139 | .0 | .0 | .0 | 3.3 | .0 | 4.6 | .0 | 4.0 | 4.1 | 4.1 | .0 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.0 | 4.1 | 4.0 | .0 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.0 | .0 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BTS USED TO COMPUTE AVG TEMP

LATITUDE = 42 N LONGITUDE = 86 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 11 | 6 | 12 | 16 | 7 | 8 | 8 | 9 | 0 |
| 10 - 19 | 0 | 0 | 0 | 6 | 6 | 10 | 12 | 6 | 8 | 7 | 8 | 0 |
| 20 - 29 | 0 | 0 | 0 | 6 | 6 | 10 | 12 | 6 | 7 | 6 | 7 | 0 |
| 30 - 39 | 0 | 0 | 0 | 6 | 6 | 8 | 11 | 6 | 6 | 6 | 5 | 0 |
| 40 - 49 | 0 | 0 | 0 | 6 | 6 | 7 | 10 | 4 | 6 | 6 | 6 | 0 |
| 50 - 59 | 0 | 0 | 0 | 6 | 3 | 7 | 9 | 4 | 6 | 5 | 3 | 0 |
| 60 - 69 | 0 | 0 | 0 | 5 | 3 | 3 | 8 | 1 | 4 | 4 | 3 | 0 |
| 70 - 79 | 0 | 0 | 0 | 5 | 0 | 2 | 6 | 1 | 3 | 3 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 2 | 0 | 1 | 2 | 1 | 3 | 2 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 2 | 0 | 1 | 2 | 1 | 3 | 2 | 0 | 0 |
| 100 - 109 | 0 | 0 | 0 | 1 | 0 | 1 | 2 | 1 | 3 | 1 | 0 | 0 |
| 110 - 119 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 2 | 1 | 0 | 0 |
| 120 - 129 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 2 | 1 | 0 | 0 |
| 130 - 139 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 2 | 1 | 0 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 43 N LONGITUDE = 86 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | 8.8 | 11.2 | 16.6 | 14.7 | 11.0 | 9.6 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | 6.5 | 7.2 | 12.3 | 16.0 | 10.7 | 9.4 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | 5.5 | 5.4 | 8.3 | 15.6 | 10.3 | 8.7 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | 5.1 | 4.3 | 6.3 | 13.5 | 9.7 | 7.7 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | 4.6 | 4.0 | 4.7 | 7.5 | 9.1 | 7.0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | 4.3 | 3.9 | 4.1 | 5.0 | 6.3 | 6.6 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | 4.3 | 3.9 | 3.9 | 4.7 | 4.3 | 6.4 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | 4.1 | 3.8 | 3.8 | 3.8 | 4.3 | 5.7 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | 4.1 | 3.8 | 3.9 | 3.8 | 4.2 | 4.5 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | 4.1 | 3.7 | 3.8 | 3.7 | .0 | .0 | .0 |
| 100 - 109 | .0 | .0 | .0 | .0 | .0 | 4.1 | 3.6 | 3.8 | 3.7 | .0 | .0 | .0 |
| 110 - 119 | .0 | .0 | .0 | .0 | .0 | 4.1 | 3.7 | 3.8 | 3.6 | .0 | .0 | .0 |
| 120 - 129 | .0 | .0 | .0 | .0 | .0 | 4.1 | 3.6 | 3.8 | 3.6 | .0 | .0 | .0 |
| 130 - 139 | .0 | .0 | .0 | .0 | .0 | 4.1 | 3.6 | 3.7 | 3.6 | .0 | .0 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | .0 | 4.0 | 3.6 | 3.7 | 3.5 | .0 | .0 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | 4.0 | 3.6 | .0 | .0 | .0 | .0 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | 4.0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | 4.0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | 4.0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | 4.0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BTS USED TO COMPUTE AVG TEMP

LATITUDE = 43 N LONGITUDE = 86 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 5 | 2 | 1 | 3 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 6 | 2 | 1 | 2 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 4 | 3 | 5 | 2 | 1 | 2 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 1 | 1 | 2 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 1 | 1 | 2 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 1 | 1 | 2 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 1 | 1 | 2 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 1 | 1 | 2 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 1 | 1 | 2 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 0 | 0 | 0 |
| 100 - 109 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 0 | 0 | 0 |
| 110 - 119 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 120 - 129 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 130 - 139 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

## TABLE 2 (Continued)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 44 N LONGITUDE = 86 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | 7.8 | 8.8 | 14.4 | 15.7 | 11.3 | 10.1 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | 7.1 | 5.7 | 12.2 | 13.7 | 11.0 | 10.0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | 5.6 | 4.9 | 9.9 | 9.7 | 10.8 | 9.5 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | 4.1 | 4.6 | 6.6 | 5.8 | 10.6 | 9.6 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | [illegible] | [illegible] | 6.0 | 5.1 | 9.5 | 9.0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | 4.3 | [illegible] | 4.7 | 4.8 | 6.3 | 7.6 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | 4.2 | 4.1 | 4.4 | 4.5 | 5.4 | 6.2 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | 4.2 | 4.0 | 4.2 | 4.3 | 5.0 | 5.2 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | 4.2 | 3.9 | 4.1 | 4.1 | 4.9 | 4.7 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | 4.1 | 3.8 | 4.0 | 4.0 | 4.6 | 4.5 | .0 |
| 100 - 109 | .0 | .0 | .0 | .0 | .0 | 4.1 | 3.7 | 3.9 | 3.5 | 4.6 | 4.4 | .0 |
| 110 - 119 | .0 | .0 | .0 | .0 | .0 | 4.1 | 3.7 | 3.9 | 3.5 | 4.6 | 4.3 | .0 |
| 120 - 129 | .0 | .0 | .0 | .0 | .0 | 4.1 | 3.7 | 3.8 | 3.9 | 4.5 | 4.3 | .0 |
| 130 - 139 | .0 | .0 | .0 | .0 | .0 | 4.1 | 3.6 | 3.9 | 3.9 | 4.5 | 4.2 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | .0 | 4.1 | 3.6 | 3.9 | 3.8 | 4.5 | 4.2 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | 4.1 | 3.6 | 3.8 | 3.8 | 4.5 | 4.2 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | 4.0 | 3.6 | .0 | 3.8 | 4.5 | 4.1 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | 4.0 | 3.5 | .0 | 3.8 | 4.4 | 4.1 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | 4.0 | 3.5 | .0 | 3.8 | 4.4 | 4.1 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | 4.0 | 3.6 | .0 | 3.8 | 4.2 | 4.1 | .0 |
| 200 - 209 | .0 | .0 | .0 | .0 | .0 | 4.0 | 3.6 | .0 | 3.7 | 4.3 | 4.1 | .0 |
| 210 - 219 | .0 | .0 | .0 | .0 | .0 | 3.7 | 3.6 | .0 | 3.7 | 4.3 | 4.1 | .0 |
| 220 - 229 | .0 | .0 | .0 | .0 | .0 | 3.7 | 3.6 | .0 | 3.7 | 4.3 | 4.1 | .0 |
| 230 - 239 | .0 | .0 | .0 | .0 | .0 | 3.7 | 3.6 | .0 | 3.7 | 4.3 | 4.1 | .0 |
| 240 - 249 | .0 | .0 | .0 | .0 | .0 | 3.7 | 3.6 | .0 | 3.7 | 4.3 | 4.1 | .0 |
| 250 - 259 | .0 | .0 | .0 | .0 | .0 | 3.7 | 3.6 | .0 | 3.7 | 4.3 | 3.9 | .0 |
| 260 - 269 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 270 - 279 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 280 - 289 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 290 - 299 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 44 N LONGITUDE = 86 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 4 | 2 | 2 | 3 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 4 | 2 | 2 | 3 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 4 | 2 | 2 | 3 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 4 | 2 | 2 | 3 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 2 | 2 | 3 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 2 | 2 | 3 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 2 | 2 | 3 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 2 | 2 | 3 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 2 | 2 | 3 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 2 | 2 | 3 | 0 |
| 100 - 109 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 2 | 2 | 3 | 0 |
| 110 - 119 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 2 | 2 | 3 | 0 |
| 120 - 129 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 2 | 2 | 3 | 0 |
| 130 - 139 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 2 | 2 | 2 | 3 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 1 | 2 | 2 | 3 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 1 | 2 | 2 | 3 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 2 | 2 | 3 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 2 | 2 | 3 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 2 | 2 | 3 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 1 | 1 | 2 | 0 |
| 200 - 209 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 1 | 1 | 2 | 0 |
| 210 - 219 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 0 |
| 220 - 229 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 0 |
| 230 - 239 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 0 |
| 240 - 249 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 0 |
| 250 - 259 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| 260 - 269 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 270 - 279 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 280 - 289 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 290 - 299 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 45 N LONGITUDE = 86 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 13.1 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 13.1 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 45 N LONGITUDE = 86 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 2 (Continued)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 43 N LONGITUDE = 87 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | 7.6 | 15.0 | 18.3 | 16.7 | 10.1 | 9.2 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | 7.2 | 12.1 | 12.0 | 13.4 | 9.6 | 8.7 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | 6.0 | 6.4 | 6.6 | 11.2 | 7.5 | 8.4 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | 4.6 | 4.6 | 4.5 | 6.5 | 6.1 | 7.5 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | 4.3 | 4.3 | 4.1 | 4.5 | 4.6 | 6.3 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | 4.1 | 4.2 | 3.9 | 4.2 | 4.5 | 5.7 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | 4.0 | 4.2 | 3.8 | 4.0 | 4.1 | 5.0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | 4.0 | 4.2 | 3.8 | 4.0 | 3.6 | 4.6 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | 4.0 | 4.2 | 3.7 | 4.2 | 3.5 | 4.4 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | 4.0 | 4.1 | 3.7 | 4.5 | 3.4 | 4.2 | .0 |
| 100 - 109 | .0 | .0 | .0 | .0 | .0 | 3.9 | 4.1 | 3.7 | 4.5 | 3.4 | 4.1 | .0 |
| 110 - 119 | .0 | .0 | .0 | .0 | .0 | 3.9 | 4.2 | 3.7 | 4.4 | 3.3 | 4.0 | .0 |
| 120 - 129 | .0 | .0 | .0 | .0 | .0 | 4.1 | .0 | 3.6 | .0 | 3.3 | .0 | .0 |
| 130 - 139 | .0 | .0 | .0 | .0 | .0 | 4.1 | .0 | 3.6 | .0 | .0 | .0 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | .0 | 4.1 | .0 | .0 | .0 | .0 | .0 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | 4.0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 43 N LONGITUDE = 87 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 3 | 1 | 2 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 3 | 1 | 2 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 3 | 1 | 2 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 3 | 1 | 2 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 3 | 1 | 2 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 3 | 1 | 2 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 3 | 1 | 2 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 3 | 1 | 2 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 1 | 2 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 1 | 1 | 2 | 0 |
| 100 - 109 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 1 | 1 | 2 | 0 |
| 110 - 119 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 1 | 1 | 1 | 0 |
| 120 - 129 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 0 |
| 130 - 139 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 44 N LONGITUDE = 87 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | 7.7 | 11.1 | 15.6 | 11.1 | 5.4 | 10.0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | 6.6 | 8.8 | 14.1 | 8.5 | 8.7 | 9.5 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | 6.0 | 6.4 | 7.1 | 6.9 | 8.4 | 9.8 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | 5.7 | 4.9 | 5.9 | 5.3 | 8.2 | 9.1 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | 6.3 | 4.4 | 5.3 | 4.9 | 7.4 | 7.9 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | 5.6 | 4.1 | 4.7 | 4.6 | 5.9 | 6.6 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | 5.2 | 4.0 | 4.3 | 4.4 | 4.9 | 5.6 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | 5.2 | 3.9 | 4.2 | 4.3 | 4.6 | 5.1 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | 5.1 | 3.8 | 4.1 | 4.2 | 4.4 | 4.8 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | 5.1 | 3.8 | 4.1 | 4.1 | 4.3 | 4.6 | .0 |
| 100 - 109 | .0 | .0 | .0 | .0 | .0 | 5.1 | 3.8 | 4.1 | 4.0 | 4.3 | 4.6 | .0 |
| 110 - 119 | .0 | .0 | .0 | .0 | .0 | 5.0 | 3.7 | 4.1 | 3.9 | 4.6 | 4.5 | .0 |
| 120 - 129 | .0 | .0 | .0 | .0 | .0 | 5.0 | 3.7 | 4.0 | 3.9 | 4.5 | 4.5 | .0 |
| 130 - 139 | .0 | .0 | .0 | .0 | .0 | 4.9 | 3.7 | 4.0 | 3.9 | 4.5 | 4.4 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | .0 | 4.5 | 3.6 | 4.0 | 3.9 | 4.5 | 4.4 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | 4.8 | 3.6 | .0 | 3.9 | 4.5 | 4.4 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | 4.7 | .0 | .0 | 3.9 | 4.5 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 44 N LONGITUDE = 87 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 1 | 2 | 1 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 1 | 2 | 1 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 1 | 2 | 1 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 1 | 2 | 1 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 |
| 100 - 109 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 |
| 110 - 119 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 120 - 129 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 130 - 139 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 2 (Continued)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 43 N LONGITUDE = 87 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | 7.6 | 15.0 | 16.3 | 16.7 | 10.1 | 9.3 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | 7.2 | 12.1 | 12.0 | 13.4 | 5.8 | 8.7 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | 6.0 | 6.4 | 6.6 | 11.2 | 7.5 | 8.4 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | 4.8 | 4.6 | 4.5 | 6.5 | 6.1 | 7.5 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | 4.3 | 4.3 | 4.1 | 4.5 | 4.6 | 6.3 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | 4.1 | 4.2 | 3.9 | 4.2 | 4.5 | 5.7 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | 4.0 | 4.2 | 3.8 | 4.0 | 4.1 | 5.0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | 4.0 | 4.2 | 3.8 | 4.0 | 3.8 | 4.6 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | 4.0 | 4.2 | 3.7 | 4.2 | 3.5 | 4.4 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | 4.0 | 4.1 | 3.7 | 4.0 | 3.4 | 4.2 | .0 |
| 100 - 109 | .0 | .0 | .0 | .0 | .0 | 3.9 | 4.1 | 3.7 | 4.5 | 3.4 | 4.1 | .0 |
| 110 - 119 | .0 | .0 | .0 | .0 | .0 | 3.9 | 4.2 | 3.7 | 4.4 | 3.3 | 4.0 | .0 |
| 120 - 129 | .0 | .0 | .0 | .0 | .0 | 4.1 | .0 | 3.6 | .0 | 3.3 | .0 | .0 |
| 130 - 139 | .0 | .0 | .0 | .0 | .0 | 4.1 | .0 | 3.6 | .0 | .0 | .0 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | .0 | 4.1 | .0 | .0 | .0 | .0 | .0 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | 4.0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BTS USED TO COMPUTE AVG TEMP

LATITUDE = 43 N LONGITUDE = 87 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 3 | 1 | 2 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 3 | 1 | 2 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 3 | 1 | 2 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 2 | 3 | 1 | 2 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 3 | 1 | 2 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 3 | 1 | 2 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 3 | 1 | 2 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 3 | 1 | 2 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 1 | 2 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 1 | 1 | 2 | 0 |
| 100 - 109 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 1 | 1 | 2 | 0 |
| 110 - 119 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 1 | 1 | 1 | 0 |
| 120 - 129 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 0 |
| 130 - 139 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 44 N LONGITUDE = 87 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | 7.7 | 11.1 | 15.4 | 11.1 | 5.4 | 10.0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | 6.6 | 8.8 | 14.1 | 8.5 | 8.7 | 9.5 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | 6.0 | 6.4 | 7.1 | 6.5 | 8.4 | 9.8 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | 5.7 | 4.9 | 5.5 | 5.3 | 8.2 | 9.1 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | 5.4 | 4.4 | 5.3 | 4.5 | 7.4 | 7.9 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | 5.6 | 4.1 | 4.7 | 4.6 | 5.5 | 6.6 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | 5.2 | 4.0 | 4.3 | 4.4 | 4.9 | 5.6 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | 5.2 | 3.9 | 4.2 | 4.3 | 4.6 | 5.1 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | 5.1 | 3.8 | 4.1 | 4.2 | 4.4 | 4.8 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | 5.1 | 3.8 | 4.1 | 4.1 | 4.3 | 4.6 | .0 |
| 100 - 109 | .0 | .0 | .0 | .0 | .0 | 5.1 | 3.8 | 4.1 | 4.0 | 4.3 | 4.5 | .0 |
| 110 - 119 | .0 | .0 | .0 | .0 | .0 | 5.0 | 3.7 | 4.1 | 3.9 | 4.6 | 4.5 | .0 |
| 120 - 129 | .0 | .0 | .0 | .0 | .0 | 5.0 | 3.7 | 4.0 | 3.9 | 4.5 | 4.5 | .0 |
| 130 - 139 | .0 | .0 | .0 | .0 | .0 | 4.9 | 3.7 | 4.0 | 3.9 | 4.5 | 4.4 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | .0 | 4.9 | 3.6 | 4.0 | 3.9 | 4.6 | 4.4 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | 4.8 | 3.6 | .0 | 3.5 | 4.5 | 4.4 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | 4.7 | .0 | .0 | 3.5 | 4.5 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BTS USED TO COMPUTE AVG TEMP

LATITUDE = 44 N LONGITUDE = 87 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 1 | 2 | 1 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 1 | 2 | 1 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 1 | 2 | 1 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 1 | 2 | 1 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 |
| 100 - 109 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 |
| 110 - 119 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 120 - 129 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 130 - 139 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 2 (Concluded)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 45 N LONGITUDE = 87 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 45 N LONGITUDE = 87 W 1964

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 3

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 45 N LONGITUDE = 85 W 1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 17.7 | .0 | .0 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 16.5 | .0 | .0 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 13.8 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 10.1 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 8.0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 6.9 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 6.5 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 5.5 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 5.4 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 45 N LONGITUDE = 85 W 1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 41 N LONGITUDE = 86 W 1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | 6.6 | .0 | 19.2 | .0 | .0 | 13.6 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | 4.3 | .0 | 15.0 | .0 | .0 | 13.9 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | 4.0 | .0 | 6.0 | .0 | .0 | 13.9 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | 3.9 | .0 | 5.2 | .0 | .0 | 11.5 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | 3.6 | .0 | 4.8 | .0 | .0 | 5.2 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | 3.6 | .0 | .0 | .0 | .0 | 5.2 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 41 N LONGITUDE = 86 W 1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 0 | 0 | 3 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 2 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 2 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 2 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 42 N LONGITUDE = 86 W 1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | 2.2 | 3.8 | 10.2 | 18.1 | 18.1 | 17.8 | 13.6 | 10.7 | 8.2 |
| 10 - 19 | .0 | .0 | .0 | 2.3 | 3.5 | 8.6 | 14.0 | 15.2 | 16.5 | 13.6 | 10.7 | 8.2 |
| 20 - 29 | .0 | .0 | .0 | 2.1 | 3.1 | 6.0 | 6.7 | 8.7 | 12.1 | 13.7 | 10.9 | 8.2 |
| 30 - 39 | .0 | .0 | .0 | 2.1 | 3.1 | 5.1 | 5.1 | 5.3 | 6.7 | 13.3 | 10.7 | 8.2 |
| 40 - 49 | .0 | .0 | .0 | 1.8 | 3.1 | 4.7 | 4.8 | 4.8 | 5.2 | 8.6 | 10.8 | 8.2 |
| 50 - 59 | .0 | .0 | .0 | 1.9 | 3.2 | 4.4 | 4.6 | 4.6 | 5.4 | 5.3 | 8.5 | 8.3 |
| 60 - 69 | .0 | .0 | .0 | 1.9 | 3.0 | 4.3 | 4.5 | 4.5 | 5.7 | 4.6 | 5.4 | 8.1 |
| 70 - 79 | .0 | .0 | .0 | 1.8 | 3.1 | 4.1 | 4.5 | 4.5 | 5.5 | 4.5 | 5.1 | 8.2 |
| 80 - 89 | .0 | .0 | .0 | 2.3 | 2.6 | 3.8 | 4.6 | 4.4 | 5.3 | 4.4 | 4.9 | 8.2 |
| 90 - 99 | .0 | .0 | .0 | 2.3 | 2.6 | 3.8 | 4.6 | 4.4 | 4.8 | 4.2 | 4.9 | 8.2 |
| | | | | | | | | | | | | |
| 100 - 109 | .0 | .0 | .0 | 2.3 | 2.9 | 3.8 | 4.5 | 4.4 | 4.5 | 4.2 | 4.7 | 8.2 |
| 110 - 119 | .0 | .0 | .0 | 2.3 | 2.9 | 3.7 | 4.9 | 4.1 | 4.4 | 4.2 | 4.6 | 8.1 |
| 120 - 129 | .0 | .0 | .0 | 2.4 | 2.9 | 3.7 | 4.8 | 4.1 | 4.4 | 4.1 | 4.6 | 8.1 |
| 130 - 139 | .0 | .0 | .0 | .0 | 2.8 | 3.7 | 4.7 | 4.1 | 4.4 | 4.1 | 4.6 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | 2.2 | 3.7 | 4.6 | 4.0 | .0 | .0 | .0 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | 3.4 | .0 | .0 | .0 | .0 | .0 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | 3.4 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | 3.4 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | 3.5 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | 3.5 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 42 N LONGITUDE = 86 W 1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 6 | 12 | 16 | 18 | 9 | 9 | 11 | 6 | 3 |
| 10 - 19 | 0 | 0 | 0 | 6 | 11 | 16 | 16 | 8 | 8 | 9 | 6 | 3 |
| 20 - 29 | 0 | 0 | 0 | 5 | 9 | 12 | 14 | 8 | 7 | 8 | 5 | 3 |
| 30 - 39 | 0 | 0 | 0 | 5 | 9 | 11 | 11 | 7 | 6 | 7 | 5 | 3 |
| 40 - 49 | 0 | 0 | 0 | 4 | 8 | 11 | 10 | 5 | 5 | 6 | 4 | 3 |
| 50 - 59 | 0 | 0 | 0 | 3 | 7 | 8 | 7 | 5 | 5 | 5 | 3 | 3 |
| 60 - 69 | 0 | 0 | 0 | 3 | 6 | 8 | 5 | 3 | 4 | 3 | 3 | 2 |
| 70 - 79 | 0 | 0 | 0 | 2 | 4 | 5 | 4 | 3 | 3 | 3 | 3 | 2 |
| 80 - 89 | 0 | 0 | 0 | 1 | 3 | 4 | 3 | 2 | 2 | 2 | 2 | 2 |
| 90 - 99 | 0 | 0 | 0 | 1 | 3 | 4 | 3 | 2 | 2 | 1 | 2 | 2 |
| | | | | | | | | | | | | |
| 100 - 109 | 0 | 0 | 0 | 1 | 2 | 3 | 2 | 2 | 1 | 1 | 1 | 2 |
| 110 - 119 | 0 | 0 | 0 | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 120 - 129 | 0 | 0 | 0 | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 130 - 139 | 0 | 0 | 0 | 0 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 1 | 0 | 0 | 0 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

## TABLE 3 (Continued)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 43 N LONGITUDE = 86 W 1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | 1.6 | 4.8 | 9.0 | 16.0 | 15.7 | 15.6 | 12.8 | 9.1 | 9.4 |
| 10 - 19 | .0 | .0 | .0 | 1.6 | 4.8 | 7.8 | 14.3 | 11.9 | 14.9 | 12.5 | 9.6 | 9.4 |
| 20 - 29 | .0 | .0 | .0 | 1.6 | 4.8 | 6.5 | 9.8 | 6.6 | 12.1 | 10.6 | 10.3 | 9.6 |
| 30 - 39 | .0 | .0 | .0 | 1.6 | 4.3 | 4.9 | 5.9 | 4.9 | 7.9 | 7.5 | 10.7 | 9.6 |
| 40 - 49 | .0 | .0 | .0 | 1.6 | 3.1 | 4.5 | 5.4 | 4.6 | 5.1 | 4.8 | 9.9 | 9.5 |
| 50 - 59 | .0 | .0 | .0 | 1.6 | 3.2 | 4.2 | 5.0 | 4.4 | 4.7 | 4.3 | 9.0 | 9.5 |
| 60 - 69 | .0 | .0 | .0 | 1.6 | 3.2 | 4.1 | 4.9 | 4.3 | 4.6 | 4.2 | 8.5 | 9.4 |
| 70 - 79 | .0 | .0 | .0 | 1.6 | 3.5 | 4.1 | 4.8 | 4.2 | 4.4 | 4.1 | 6.9 | 9.4 |
| 80 - 89 | .0 | .0 | .0 | 1.6 | 4.0 | 4.1 | 4.7 | 4.2 | 4.3 | 4.1 | 5.4 | 9.3 |
| 90 - 99 | .0 | .0 | .0 | 1.6 | 4.0 | 4.0 | 4.7 | 4.2 | 3.9 | 4.0 | .0 | 9.3 |
| 100 - 109 | .0 | .0 | .0 | 1.6 | 4.0 | 3.9 | 4.7 | 4.2 | 3.9 | .0 | .0 | .0 |
| 110 - 119 | .0 | .0 | .0 | 1.6 | 4.0 | 3.7 | 4.6 | 4.2 | 3.8 | .0 | .0 | .0 |
| 120 - 129 | .0 | .0 | .0 | 1.6 | .0 | 3.6 | 4.6 | 4.2 | .0 | .0 | .0 | .0 |
| 130 - 139 | .0 | .0 | .0 | 1.6 | .0 | 3.6 | 4.5 | 4.2 | .0 | .0 | .0 | .0 |
| 140 - 149 | .0 | .0 | .0 | 1.6 | .0 | 3.6 | 4.5 | 4.1 | .0 | .0 | .0 | .0 |
| 150 - 159 | .0 | .0 | .0 | 1.7 | .0 | 3.5 | 4.4 | 4.1 | .0 | .0 | .0 | .0 |
| 160 - 169 | .0 | .0 | .0 | 1.9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 43 N LONGITUDE = 86 W 1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 2 | 5 | 5 | 6 | 5 | 5 | 5 | 6 | 1 |
| 10 - 19 | 0 | 0 | 0 | 2 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 1 |
| 20 - 29 | 0 | 0 | 0 | 2 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 1 |
| 30 - 39 | 0 | 0 | 0 | 2 | 4 | 3 | 4 | 4 | 3 | 4 | 3 | 1 |
| 40 - 49 | 0 | 0 | 0 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 1 |
| 50 - 59 | 0 | 0 | 0 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 1 |
| 60 - 69 | 0 | 0 | 0 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 1 |
| 70 - 79 | 0 | 0 | 0 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 1 |
| 80 - 89 | 0 | 0 | 0 | 1 | 2 | 3 | 3 | 3 | 2 | 3 | 2 | 1 |
| 90 - 99 | 0 | 0 | 0 | 1 | 2 | 3 | 3 | 2 | 1 | 1 | 0 | 1 |
| 100 - 109 | 0 | 0 | 0 | 1 | 1 | 2 | 1 | 2 | 1 | 0 | 0 | 0 |
| 110 - 119 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 120 - 129 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 130 - 139 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 140 - 149 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 150 - 159 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 160 - 169 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 44 N LONGITUDE = 86 W 1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | 1.8 | 2.8 | 5.9 | 14.6 | 17.1 | 14.6 | 12.6 | 8.4 | .0 |
| 10 - 19 | .0 | .0 | .0 | 1.8 | 2.8 | 5.6 | 10.6 | 15.8 | 14.3 | 12.6 | 8.4 | .0 |
| 20 - 29 | .0 | .0 | .0 | 1.8 | 2.9 | 5.3 | 7.2 | 11.7 | 10.9 | 12.3 | 8.4 | .0 |
| 30 - 39 | .0 | .0 | .0 | 1.8 | 2.9 | 5.0 | 6.3 | 8.3 | 5.8 | 9.4 | 8.4 | .0 |
| 40 - 49 | .0 | .0 | .0 | 1.8 | 2.9 | 4.2 | 5.0 | 6.3 | 4.7 | 5.6 | 8.5 | .0 |
| 50 - 59 | .0 | .0 | .0 | 1.8 | 2.7 | 4.2 | 4.9 | 5.9 | 4.4 | 4.4 | 6.9 | .0 |
| 60 - 69 | .0 | .0 | .0 | 1.9 | 2.7 | 4.1 | 4.7 | 5.6 | 4.3 | 4.2 | 5.3 | .0 |
| 70 - 79 | .0 | .0 | .0 | 1.9 | 2.7 | 4.0 | 4.6 | 5.4 | 4.2 | 4.1 | 5.0 | .0 |
| 80 - 89 | .0 | .0 | .0 | 1.9 | 2.7 | 4.0 | 4.5 | 5.2 | 4.2 | 4.0 | 4.7 | .0 |
| 90 - 99 | .0 | .0 | .0 | 2.0 | 2.7 | 4.0 | 4.5 | 4.5 | 4.1 | 3.9 | 4.5 | .0 |
| 100 - 109 | .0 | .0 | .0 | 2.0 | 2.7 | 4.0 | 4.5 | 4.4 | 4.1 | 3.9 | 4.2 | .0 |
| 110 - 119 | .0 | .0 | .0 | 2.1 | 2.7 | 4.0 | 4.4 | 4.4 | 4.0 | 3.8 | 4.1 | .0 |
| 120 - 129 | .0 | .0 | .0 | 2.1 | 2.7 | 3.9 | 4.4 | 4.3 | 4.0 | 3.8 | 4.1 | .0 |
| 130 - 139 | .0 | .0 | .0 | 2.2 | 2.7 | 3.9 | 4.4 | 4.3 | 4.0 | 3.8 | 4.0 | .0 |
| 140 - 149 | .0 | .0 | .0 | 2.4 | 2.7 | 3.9 | 4.4 | 4.2 | 3.9 | 3.8 | 4.0 | .0 |
| 150 - 159 | .0 | .0 | .0 | 2.5 | 2.7 | 3.9 | 4.3 | 4.2 | 3.9 | 3.7 | 3.9 | .0 |
| 160 - 169 | .0 | .0 | .0 | 2.8 | 2.7 | 3.8 | 4.3 | 4.2 | 3.9 | 3.7 | 3.9 | .0 |
| 170 - 179 | .0 | .0 | .0 | 2.8 | 2.7 | 3.8 | 4.3 | 4.2 | 3.9 | 3.7 | 3.9 | .0 |
| 180 - 189 | .0 | .0 | .0 | 2.9 | 2.7 | 3.8 | 4.2 | 4.1 | 3.8 | 3.6 | 3.8 | .0 |
| 190 - 199 | .0 | .0 | .0 | 2.9 | 2.6 | 3.4 | 4.2 | 3.7 | 3.7 | 3.6 | 3.7 | .0 |
| 200 - 209 | .0 | .0 | .0 | 3.0 | 2.7 | 3.4 | 4.2 | 3.7 | 3.6 | 3.6 | 3.7 | .0 |
| 210 - 219 | .0 | .0 | .0 | 2.8 | 2.7 | 3.3 | 4.2 | 3.7 | 3.6 | 3.7 | 3.7 | .0 |
| 220 - 229 | .0 | .0 | .0 | 2.8 | 2.7 | 3.3 | 4.2 | 3.7 | 3.6 | 3.7 | 3.7 | .0 |
| 230 - 239 | .0 | .0 | .0 | 2.9 | 2.7 | 3.3 | 4.2 | 3.6 | 3.6 | 3.7 | 3.6 | .0 |
| 240 - 249 | .0 | .0 | .0 | 2.9 | 2.8 | 3.3 | 4.1 | 3.6 | 3.6 | 3.7 | 3.6 | .0 |
| 250 - 259 | .0 | .0 | .0 | .0 | 3.1 | 3.3 | .0 | .0 | .0 | .0 | .0 | .0 |
| 260 - 269 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 270 - 279 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 280 - 289 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 290 - 299 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 44 N LONGITUDE = 86 W 1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 4 | 6 | 4 | 4 | 4 | 4 | 4 | 4 | 0 |
| 10 - 19 | 0 | 0 | 0 | 4 | 6 | 4 | 4 | 4 | 4 | 4 | 4 | 0 |
| 20 - 29 | 0 | 0 | 0 | 4 | 6 | 4 | 4 | 4 | 4 | 4 | 4 | 0 |
| 30 - 39 | 0 | 0 | 0 | 4 | 6 | 4 | 4 | 4 | 4 | 4 | 4 | 0 |
| 40 - 49 | 0 | 0 | 0 | 4 | 6 | 3 | 4 | 3 | 3 | 3 | 3 | 0 |
| 50 - 59 | 0 | 0 | 0 | 4 | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 0 |
| 60 - 69 | 0 | 0 | 0 | 4 | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 0 |
| 70 - 79 | 0 | 0 | 0 | 4 | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 0 |
| 80 - 89 | 0 | 0 | 0 | 4 | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 0 |
| 90 - 99 | 0 | 0 | 0 | 3 | 5 | 3 | 3 | 2 | 3 | 3 | 3 | 0 |
| 100 - 109 | 0 | 0 | 0 | 3 | 5 | 3 | 3 | 2 | 3 | 3 | 3 | 0 |
| 110 - 119 | 0 | 0 | 0 | 3 | 5 | 3 | 3 | 2 | 3 | 3 | 3 | 0 |
| 120 - 129 | 0 | 0 | 0 | 3 | 5 | 3 | 3 | 2 | 3 | 3 | 3 | 0 |
| 130 - 139 | 0 | 0 | 0 | 3 | 5 | 3 | 3 | 2 | 3 | 3 | 3 | 0 |
| 140 - 149 | 0 | 0 | 0 | 3 | 5 | 3 | 3 | 2 | 3 | 3 | 3 | 0 |
| 150 - 159 | 0 | 0 | 0 | 3 | 5 | 3 | 3 | 2 | 3 | 3 | 3 | 0 |
| 160 - 169 | 0 | 0 | 0 | 2 | 5 | 3 | 3 | 2 | 3 | 3 | 3 | 0 |
| 170 - 179 | 0 | 0 | 0 | 2 | 5 | 3 | 3 | 2 | 3 | 3 | 3 | 0 |
| 180 - 189 | 0 | 0 | 0 | 2 | 4 | 3 | 2 | 2 | 3 | 2 | 3 | 0 |
| 190 - 199 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 0 |
| 200 - 209 | 0 | 0 | 0 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 0 |
| 210 - 219 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 0 |
| 220 - 229 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 0 |
| 230 - 239 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 240 - 249 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 250 - 259 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 260 - 269 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 270 - 279 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 280 - 289 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 290 - 299 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## TABLE 3 (Continued)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 45 N  LONGITUDE = 86 W   1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 18.1 | .0 | .0 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 14.9 | .0 | .0 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 10.0 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 7.2 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 5.9 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 5.4 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 5.1 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 5.0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 5.0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 5.0 | .0 | .0 | .0 | .0 |
| 100 - 109 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.9 | .0 | .0 | .0 | .0 |
| 110 - 119 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.8 | .0 | .0 | .0 | .0 |
| 120 - 129 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.8 | .0 | .0 | .0 | .0 |
| 130 - 139 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.5 | .0 | .0 | .0 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.5 | .0 | .0 | .0 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.4 | .0 | .0 | .0 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.4 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.4 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 45 N  LONGITUDE = 86 W   1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| 100 - 109 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| 110 - 119 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| 120 - 129 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| 130 - 139 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 41 N  LONGITUDE = 87 W   1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | 8.3 | 11.9 | 20.3 | 21.1 | 18.4 | 12.8 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | 4.8 | 10.2 | 14.4 | 18.6 | 18.6 | 13.0 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | 3.8 | 7.4 | 5.4 | 6.3 | 14.6 | 12.3 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | 3.7 | 5.6 | 5.4 | 6.0 | .0 | 8.8 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 41 N  LONGITUDE = 87 W   1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 7 | 3 | 7 | 2 | 2 | 5 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 1 | 1 | 3 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 1 | 1 | 2 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 1 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 3 (Continued)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 42 N  LONGITUDE = 87 W  1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | 2.0 | 3.3 | 8.2 | 16.4 | 19.6 | 17.7 | 12.1 | 9.3 | 7.6 |
| 10 - 19 | .0 | .0 | .0 | 2.0 | 3.0 | 6.6 | 12.0 | 18.2 | 17.6 | 11.8 | 9.3 | 7.6 |
| 20 - 29 | .0 | .0 | .0 | 2.0 | 2.9 | 5.3 | 7.3 | 7.8 | 10.7 | 11.1 | 9.3 | 7.6 |
| 30 - 39 | .0 | .0 | .0 | 2.0 | 2.9 | 4.8 | 5.7 | 5.4 | 5.3 | 9.6 | 9.3 | 7.6 |
| 40 - 49 | .0 | .0 | .0 | 2.1 | 2.8 | 4.2 | 5.2 | 4.7 | 4.7 | 7.0 | 8.7 | 7.8 |
| 50 - 59 | .0 | .0 | .0 | .0 | 2.7 | 4.0 | 4.9 | 4.5 | 4.4 | 4.5 | 5.6 | 7.8 |
| 60 - 69 | .0 | .0 | .0 | .0 | 2.8 | 3.8 | 4.8 | 4.3 | 4.4 | 4.4 | 5.0 | 7.8 |
| 70 - 79 | .0 | .0 | .0 | .0 | 2.7 | 3.8 | 4.9 | 4.1 | 4.4 | 4.4 | 5.0 | 7.8 |
| 80 - 89 | .0 | .0 | .0 | .0 | 2.8 | 4.0 | 4.8 | 4.1 | 4.3 | 4.3 | 4.9 | 7.8 |
| 90 - 99 | .0 | .0 | .0 | .0 | 2.8 | 4.0 | 5.0 | 4.2 | 4.0 | 4.3 | .0 | 7.8 |
| 100 - 109 | .0 | .0 | .0 | .0 | 3.0 | 3.7 | 5.5 | .0 | 4.0 | .0 | .0 | 7.8 |
| 110 - 119 | .0 | .0 | .0 | .0 | 3.8 | 3.5 | 5.0 | .0 | 4.0 | .0 | .0 | 7.4 |
| 120 - 129 | .0 | .0 | .0 | .0 | .0 | 3.5 | 5.0 | .0 | .0 | .0 | .0 | 6.7 |
| 130 - 139 | .0 | .0 | .0 | .0 | .0 | 3.5 | .0 | .0 | .0 | .0 | .0 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | .0 | 3.5 | .0 | .0 | .0 | .0 | .0 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | 3.5 | .0 | .0 | .0 | .0 | .0 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | 3.5 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | 3.5 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | 3.5 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | 3.4 | .0 | .0 | .0 | .0 | .0 | .0 |
| 200 - 209 | .0 | .0 | .0 | .0 | .0 | 3.4 | .0 | .0 | .0 | .0 | .0 | .0 |
| 210 - 219 | .0 | .0 | .0 | .0 | .0 | 3.4 | .0 | .0 | .0 | .0 | .0 | .0 |
| 220 - 229 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 230 - 239 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 240 - 249 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 250 - 259 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 260 - 269 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 270 - 279 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 280 - 289 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 290 - 299 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 42 N  LONGITUDE = 87 W  1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 1 | 13 | 11 | 11 | 7 | 8 | 2 | 3 | 3 |
| 10 - 19 | 0 | 0 | 0 | 1 | 12 | 10 | 10 | 7 | 7 | 2 | 3 | 3 |
| 20 - 29 | 0 | 0 | 0 | 1 | 12 | 10 | 10 | 7 | 7 | 2 | 3 | 3 |
| 30 - 39 | 0 | 0 | 0 | 1 | 12 | 10 | 10 | 7 | 7 | 2 | 3 | 3 |
| 40 - 49 | 0 | 0 | 0 | 1 | 10 | 8 | 9 | 5 | 6 | 2 | 3 | 2 |
| 50 - 59 | 0 | 0 | 0 | 0 | 8 | 7 | 8 | 5 | 5 | 1 | 1 | 2 |
| 60 - 69 | 0 | 0 | 0 | 0 | 8 | 6 | 8 | 5 | 5 | 1 | 1 | 2 |
| 70 - 79 | 0 | 0 | 0 | 0 | 5 | 6 | 6 | 3 | 4 | 1 | 1 | 2 |
| 80 - 89 | 0 | 0 | 0 | 0 | 3 | 4 | 5 | 2 | 3 | 1 | 1 | 2 |
| 90 - 99 | 0 | 0 | 0 | 0 | 3 | 3 | 4 | 1 | 2 | 1 | 0 | 2 |
| 100 - 109 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 1 | 0 | 0 | 2 |
| 110 - 119 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| 120 - 129 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 |
| 130 - 139 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 200 - 209 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 210 - 219 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 220 - 229 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 230 - 239 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 240 - 249 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 250 - 259 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 260 - 269 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 270 - 279 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 280 - 289 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 290 - 299 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 43 N  LONGITUDE = 87 W  1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | 1.6 | 3.0 | 10.6 | 15.5 | 18.6 | 16.5 | 10.7 | 7.9 | 7.2 |
| 10 - 19 | .0 | .0 | .0 | 1.7 | 2.9 | 8.1 | 11.2 | 17.5 | 13.1 | 9.9 | 7.9 | 7.2 |
| 20 - 29 | .0 | .0 | .0 | 1.7 | 2.7 | 6.5 | 6.4 | 15.1 | 9.4 | 9.6 | 7.7 | 7.2 |
| 30 - 39 | .0 | .0 | .0 | 1.7 | 2.4 | 5.5 | 5.4 | 7.4 | 5.5 | 9.0 | 7.9 | 7.2 |
| 40 - 49 | .0 | .0 | .0 | 1.6 | 2.4 | 5.0 | 5.0 | 5.2 | 4.4 | 5.9 | 7.9 | 7.2 |
| 50 - 59 | .0 | .0 | .0 | 1.6 | 2.4 | 4.9 | 4.7 | 4.6 | 4.2 | 5.0 | 7.4 | 7.2 |
| 60 - 69 | .0 | .0 | .0 | 1.6 | 2.4 | 4.8 | 4.6 | 4.5 | 4.1 | 4.7 | 6.3 | 7.2 |
| 70 - 79 | .0 | .0 | .0 | 1.6 | 2.4 | 4.7 | 4.5 | 4.4 | 4.0 | 4.5 | 5.3 | 7.2 |
| 80 - 89 | .0 | .0 | .0 | 1.6 | 2.4 | 4.8 | 4.4 | 4.4 | 4.0 | 4.4 | 4.8 | 7.2 |
| 90 - 99 | .0 | .0 | .0 | 1.6 | 2.4 | 4.8 | 4.6 | 4.5 | 3.8 | 4.4 | 4.6 | .0 |
| 100 - 109 | .0 | .0 | .0 | 1.6 | 2.4 | 5.0 | 4.5 | 4.5 | 3.8 | 4.4 | 4.4 | .0 |
| 110 - 119 | .0 | .0 | .0 | 1.8 | 2.4 | 5.0 | 4.5 | 4.5 | 3.7 | 4.3 | 4.3 | .0 |
| 120 - 129 | .0 | .0 | .0 | 1.8 | 2.4 | 5.8 | 4.4 | 4.5 | .0 | 4.0 | 4.3 | .0 |
| 130 - 139 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.2 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.2 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.2 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 43 N  LONGITUDE = 87 W  1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 4 | 5 | 8 | 7 | 7 | 6 | 3 | 4 | 1 |
| 10 - 19 | 0 | 0 | 0 | 4 | 5 | 8 | 6 | 6 | 5 | 3 | 4 | 1 |
| 20 - 29 | 0 | 0 | 0 | 4 | 5 | 8 | 6 | 6 | 5 | 3 | 4 | 1 |
| 30 - 39 | 0 | 0 | 0 | 3 | 4 | 8 | 5 | 5 | 4 | 2 | 3 | 1 |
| 40 - 49 | 0 | 0 | 0 | 2 | 4 | 7 | 5 | 5 | 4 | 2 | 3 | 1 |
| 50 - 59 | 0 | 0 | 0 | 2 | 4 | 5 | 4 | 4 | 4 | 2 | 3 | 1 |
| 60 - 69 | 0 | 0 | 0 | 2 | 4 | 5 | 4 | 4 | 3 | 2 | 3 | 1 |
| 70 - 79 | 0 | 0 | 0 | 2 | 4 | 5 | 4 | 4 | 3 | 2 | 3 | 1 |
| 80 - 89 | 0 | 0 | 0 | 2 | 4 | 4 | 4 | 4 | 3 | 2 | 3 | 1 |
| 90 - 99 | 0 | 0 | 0 | 2 | 4 | 3 | 2 | 2 | 1 | 2 | 3 | 0 |
| 100 - 109 | 0 | 0 | 0 | 2 | 4 | 2 | 2 | 1 | 1 | 2 | 3 | 0 |
| 110 - 119 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 3 | 0 |
| 120 - 129 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 1 | 0 | 1 | 2 | 0 |
| 130 - 139 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 3 (Concluded)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 44 N LONGITUDE = 87 W 1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | 2.0 | 4.0 | 8.8 | 13.5 | 18.1 | 14.0 | 9.6 | 8.2 | .0 |
| 10 - 19 | .0 | .0 | .0 | 2.2 | 3.2 | 7.0 | 10.0 | 15.1 | 14.0 | 9.6 | 8.0 | .0 |
| 20 - 29 | .0 | .0 | .0 | 1.6 | 2.9 | 6.0 | 5.9 | 6.5 | 10.4 | 9.2 | 8.0 | .0 |
| 30 - 39 | .0 | .0 | .0 | 1.6 | 2.4 | 4.9 | 5.4 | 4.5 | 4.1 | 7.6 | 8.9 | .0 |
| 40 - 49 | .0 | .0 | .0 | 1.6 | 2.5 | 4.5 | 5.2 | 4.5 | 3.6 | .0 | 8.9 | .0 |
| 50 - 59 | .0 | .0 | .0 | 1.6 | 2.5 | 4.4 | 4.9 | 4.4 | 3.5 | .0 | 8.8 | .0 |
| 60 - 69 | .0 | .0 | .0 | 1.6 | 2.5 | 4.4 | 4.7 | 4.4 | 3.4 | .0 | 7.5 | .0 |
| 70 - 79 | .0 | .0 | .0 | 1.6 | 2.5 | 4.4 | 4.8 | 4.3 | 3.3 | .0 | 4.3 | .0 |
| 80 - 89 | .0 | .0 | .0 | 1.6 | 2.5 | 4.4 | 4.5 | 4.3 | 3.2 | .0 | 3.9 | .0 |
| 90 - 99 | .0 | .0 | .0 | 1.6 | 2.5 | 4.4 | 4.5 | 4.2 | 3.1 | .0 | 3.8 | .0 |
| 100 - 109 | .0 | .0 | .0 | 1.9 | 2.5 | 4.4 | 4.5 | 4.2 | 3.1 | .0 | 3.8 | .0 |
| 110 - 119 | .0 | .0 | .0 | 2.3 | 2.5 | 4.4 | 4.4 | 4.2 | 3.1 | .0 | 3.7 | .0 |
| 120 - 129 | .0 | .0 | .0 | 2.6 | 2.5 | 4.3 | 4.4 | 4.1 | 3.1 | .0 | 3.7 | .0 |
| 130 - 139 | .0 | .0 | .0 | .0 | 2.5 | .0 | 4.3 | 4.1 | 3.0 | .0 | 3.7 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | 2.6 | .0 | 4.3 | 4.1 | 3.0 | .0 | 3.7 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | 2.7 | .0 | 4.3 | 4.0 | .0 | .0 | 3.6 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | .0 | 4.2 | .0 | .0 | .0 | 3.6 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 44 N LONGITUDE = 87 W 1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 4 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 0 |
| 10 - 19 | 0 | 0 | 0 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 0 |
| 20 - 29 | 0 | 0 | 0 | 1 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 0 |
| 30 - 39 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 0 |
| 40 - 49 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 1 | 1 | 0 | 1 | 0 |
| 50 - 59 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 60 - 69 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 70 - 79 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 80 - 89 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 90 - 99 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 100 - 109 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 110 - 119 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 120 - 129 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 130 - 139 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 45 N LONGITUDE = 87 W 1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 19.4 | .0 | .0 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 16.2 | .0 | .0 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 45 N LONGITUDE = 87 W 1965

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 4

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 45 N  LONGITUDE = 85 W  1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TC COMPUTE AVG TEMP

LATITUDE = 45 N  LONGITUDE = 85 W  1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 41 N  LONGITUDE = 86 W  1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | 2.7 | .0 | .0 | 15.7 | .0 | .0 | .0 | .0 | .0 | .0 |
| 10 - 19 | .0 | .0 | 2.5 | .0 | .0 | 9.6 | .0 | .0 | .0 | .0 | .0 | .0 |
| 20 - 29 | .0 | .0 | 2.5 | .0 | .0 | 6.2 | .0 | .0 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | 2.5 | .0 | .0 | 4.6 | .0 | .0 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | 3.0 | .0 | .0 | 4.6 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TC COMPUTE AVG TEMP

LATITUDE = 41 N  LONGITUDE = 86 W  1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 3 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 - 19 | 0 | 0 | 2 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 - 29 | 0 | 0 | 2 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 42 N  LONGITUDE = 86 W  1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | 1.8 | 3.5 | 5.3 | 12.5 | .0 | 19.8 | 17.1 | 13.5 | 9.9 | 4.3 |
| 10 - 19 | .0 | .0 | 1.8 | 3.4 | 5.2 | 8.8 | .0 | 16.9 | 15.7 | 13.4 | 9.6 | 4.3 |
| 20 - 29 | .0 | .0 | 1.8 | 3.2 | 4.9 | 6.5 | .0 | 9.6 | 13.6 | 12.7 | 9.3 | 4.4 |
| 30 - 39 | .0 | .0 | 1.8 | 3.1 | 4.8 | 5.3 | .0 | 5.9 | 10.2 | 7.5 | 9.4 | 4.4 |
| 40 - 49 | .0 | .0 | 1.8 | 3.0 | 4.5 | 4.8 | .0 | 5.4 | 6.9 | 5.2 | 8.9 | 4.4 |
| 50 - 59 | .0 | .0 | 2.0 | 3.1 | 4.5 | 4.6 | .0 | 5.4 | 4.7 | .0 | 7.6 | 4.4 |
| 60 - 69 | .0 | .0 | 2.0 | 3.0 | 4.0 | 4.3 | .0 | 5.7 | 4.3 | .0 | 6.1 | 4.1 |
| 70 - 79 | .0 | .0 | 2.3 | 3.2 | 4.0 | 3.7 | .0 | 7.3 | 4.2 | .0 | 5.6 | 3.8 |
| 80 - 89 | .0 | .0 | 2.4 | 3.2 | 4.0 | 3.6 | .0 | 7.9 | 4.1 | .0 | 5.7 | 3.8 |
| 90 - 99 | .0 | .0 | 2.3 | 3.1 | 4.0 | 4.1 | .0 | 5.1 | 4.6 | .0 | 5.0 | .0 |
| 100 - 109 | .0 | .0 | 2.3 | 3.1 | 3.9 | 4.0 | .0 | 5.1 | 4.6 | .0 | 4.4 | .0 |
| 110 - 119 | .0 | .0 | 2.2 | 3.2 | 3.9 | 4.0 | .0 | 5.0 | 4.6 | .0 | 4.4 | .0 |
| 120 - 129 | .0 | .0 | 2.2 | 2.8 | 3.9 | 3.9 | .0 | 5.0 | 4.5 | .0 | 4.4 | .0 |
| 130 - 139 | .0 | .0 | 2.2 | 2.8 | 3.9 | 3.8 | .0 | 4.9 | 4.5 | .0 | 4.4 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | 3.9 | 3.8 | .0 | 4.4 | .0 | .0 | 4.3 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TC COMPUTE AVG TEMP

LATITUDE = 42 N  LONGITUDE = 86 W  1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 10 | 16 | 4 | 18 | 0 | 12 | 8 | 3 | 14 | 4 |
| 10 - 19 | 0 | 0 | 9 | 15 | 4 | 16 | 0 | 11 | 7 | 2 | 12 | 4 |
| 20 - 29 | 0 | 0 | 8 | 14 | 4 | 14 | 0 | 9 | 6 | 1 | 10 | 4 |
| 30 - 39 | 0 | 0 | 7 | 13 | 4 | 13 | 0 | 9 | 5 | 1 | 9 | 4 |
| 40 - 49 | 0 | 0 | 7 | 12 | 4 | 12 | 0 | 8 | 5 | 1 | 7 | 4 |
| 50 - 59 | 0 | 0 | 5 | 10 | 4 | 10 | 0 | 7 | 4 | 0 | 6 | 3 |
| 60 - 69 | 0 | 0 | 3 | 7 | 2 | 6 | 0 | 6 | 3 | 0 | 6 | 2 |
| 70 - 79 | 0 | 0 | 2 | 5 | 1 | 4 | 0 | 4 | 2 | 0 | 3 | 1 |
| 80 - 89 | 0 | 0 | 2 | 5 | 1 | 4 | 0 | 4 | 2 | 0 | 2 | 1 |
| 90 - 99 | 0 | 0 | 1 | 4 | 1 | 2 | 0 | 2 | 1 | 0 | 2 | 0 |
| 100 - 109 | 0 | 0 | 1 | 4 | 1 | 2 | 0 | 2 | 1 | 0 | 1 | 0 |
| 110 - 119 | 0 | 0 | 1 | 4 | 1 | 2 | 0 | 2 | 1 | 0 | 1 | 0 |
| 120 - 129 | 0 | 0 | 1 | 2 | 1 | 2 | 0 | 2 | 1 | 0 | 1 | 0 |
| 130 - 139 | 0 | 0 | 1 | 2 | 1 | 2 | 0 | 2 | 1 | 0 | 1 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## TABLE 4 (Continued)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 43 N LONGITUDE = 86 W 1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | 2.9 | 6.1 | 6.8 | .0 | .0 | 17.5 | .0 | 8.2 | .0 |
| 10 - 19 | .0 | .0 | .0 | 2.3 | 3.3 | 5.4 | .0 | .0 | 17.1 | .0 | 8.1 | .0 |
| 20 - 29 | .0 | .0 | .0 | 2.3 | 3.3 | 4.4 | .0 | .0 | 10.5 | .0 | 8.0 | .0 |
| 30 - 39 | .0 | .0 | .0 | 2.2 | 3.3 | 3.6 | .0 | .0 | 5.2 | .0 | 7.9 | .0 |
| 40 - 49 | .0 | .0 | .0 | 2.2 | 3.3 | 3.5 | .0 | .0 | 4.7 | .0 | 7.8 | .0 |
| 50 - 59 | .0 | .0 | .0 | 2.2 | 3.3 | 3.5 | .0 | .0 | 4.3 | .0 | 7.6 | .0 |
| 60 - 69 | .0 | .0 | .0 | 2.2 | 3.2 | 3.4 | .0 | .0 | 4.0 | .0 | 7.4 | .0 |
| 70 - 79 | .0 | .0 | .0 | 2.1 | 3.2 | 3.4 | .0 | .0 | 4.0 | .0 | 6.4 | .0 |
| 80 - 89 | .0 | .0 | .0 | 2.5 | .0 | 3.7 | .0 | .0 | 4.0 | .0 | 5.7 | .0 |
| 90 - 99 | .0 | .0 | .0 | 3.0 | .0 | 3.5 | .0 | .0 | 4.0 | .0 | 5 1 | .0 |
| 100 - 109 | .0 | .0 | .0 | 3.0 | .0 | .0 | .0 | .0 | 4.0 | .0 | 4.8 | .0 |
| 110 - 119 | .0 | .0 | .0 | 3.2 | .0 | .0 | .0 | .0 | 3.9 | .0 | 4.7 | .0 |
| 120 - 129 | .0 | .0 | .0 | 3.2 | .0 | .0 | .0 | .0 | 3.9 | .0 | 4.6 | .0 |
| 130 - 139 | .0 | .0 | .0 | 3.2 | .0 | .0 | .0 | .0 | 3.9 | .0 | 4.5 | .0 |
| 140 - 149 | .0 | .0 | .0 | 3.2 | .0 | .0 | .0 | .0 | 3.9 | .0 | 4.4 | .0 |
| 150 - 159 | .0 | .0 | .0 | 3.2 | .0 | .0 | .0 | .0 | 3.9 | .0 | 4.3 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TC COMPUTE AVG TEMP

LATITUDE = 43 N LONGITUDE = 86 W 1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 11 | 6 | 5 | 0 | 0 | 2 | 0 | 1 | 0 |
| 10 - 19 | 0 | 0 | 0 | 10 | 1 | 5 | 0 | 0 | 2 | 0 | 1 | 0 |
| 20 - 29 | 0 | 0 | 0 | 10 | 1 | 5 | 0 | 0 | 2 | 0 | 1 | 0 |
| 30 - 39 | 0 | 0 | 0 | 7 | 1 | 3 | 0 | 0 | 2 | 0 | 1 | 0 |
| 40 - 49 | 0 | 0 | 0 | 6 | 1 | 3 | 0 | 0 | 2 | 0 | 1 | 0 |
| 50 - 59 | 0 | 0 | 0 | 6 | 1 | 3 | 0 | 0 | 1 | 0 | 1 | 0 |
| 60 - 69 | 0 | 0 | 0 | 6 | 1 | 3 | 0 | 0 | 1 | 0 | 1 | 0 |
| 70 - 79 | 0 | 0 | 0 | 5 | 1 | 3 | 0 | 0 | 1 | 0 | 1 | 0 |
| 80 - 89 | 0 | 0 | 0 | 4 | 0 | 2 | 0 | 0 | 1 | 0 | 1 | 0 |
| 90 - 99 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| 100 - 109 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 110 - 119 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 120 - 129 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 130 - 139 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 140 - 149 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 150 - 159 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 44 N LONGITUDE = 86 W 1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | 4.0 | 3.5 | 8.7 | .0 | 19.8 | 17.5 | 11.2 | 6.5 | .0 |
| 10 - 19 | .0 | .0 | .0 | 4.1 | 3.5 | 6.5 | .0 | 15.0 | 17.1 | 10.4 | 6.4 | .0 |
| 20 - 29 | .0 | .0 | .0 | 4.3 | 3.5 | 5.1 | .0 | 8.2 | 9.0 | 9.5 | 6.3 | .0 |
| 30 - 39 | .0 | .0 | .0 | 2.8 | 3.5 | 4.4 | .0 | 6.6 | 5.5 | 8.4 | 6.2 | .0 |
| 40 - 49 | .0 | .0 | .0 | 2.8 | 3.5 | 4.2 | .0 | 5.9 | 5.3 | 6.2 | 5.9 | .0 |
| 50 - 59 | .0 | .0 | .0 | 2.8 | 3.4 | 4.2 | .0 | 5.8 | 5.2 | 5.5 | 5.7 | .0 |
| 60 - 69 | .0 | .0 | .0 | 2.8 | 3.4 | 4.1 | .0 | 5.7 | 5.1 | 4.9 | 5.4 | .0 |
| 70 - 79 | .0 | .0 | .0 | 2.8 | 3.4 | 4.1 | .0 | 5.6 | 5.1 | 4.7 | 5.1 | .0 |
| 80 - 89 | .0 | .0 | .0 | 2.9 | 3.4 | 4.1 | .0 | 5.6 | 5.0 | 4.6 | 5.0 | .0 |
| 90 - 99 | .0 | .0 | .0 | 2.9 | 3.4 | 4.1 | .0 | 5.5 | 5.0 | 4.5 | 4.8 | .0 |
| 100 - 109 | .0 | .0 | .0 | 2.9 | 3.4 | 4.1 | .0 | 5.4 | 4.9 | 4.5 | 4.7 | .0 |
| 110 - 119 | .0 | .0 | .0 | 2.9 | 3.4 | 4.1 | .0 | 5.4 | 4.9 | 4.4 | 4.6 | .0 |
| 120 - 129 | .0 | .0 | .0 | 2.9 | 3.4 | 4.1 | .0 | 5.3 | 4.8 | 4.4 | 4.6 | .0 |
| 130 - 139 | .0 | .0 | .0 | 2.9 | 3.4 | 4.1 | .0 | 5.2 | 4.8 | 4.4 | 4.5 | .0 |
| 140 - 149 | .0 | .0 | .0 | 3.0 | 3.3 | 4.1 | .0 | 5.2 | 4.7 | 4.4 | 4.4 | .0 |
| 150 - 159 | .0 | .0 | .0 | 3.0 | 3.3 | 4.1 | .0 | 5.1 | 4.7 | 4.4 | 4.4 | .0 |
| 160 - 169 | .0 | .0 | .0 | 3.0 | 3.3 | 4.0 | .0 | 5.0 | 4.6 | 4.3 | 4.3 | .0 |
| 170 - 179 | .0 | .0 | .0 | 3.0 | 3.3 | 3.9 | .0 | 5.0 | 4.6 | 4.3 | 4.2 | .0 |
| 180 - 189 | .0 | .0 | .0 | 3.1 | 3.3 | 3.9 | .0 | 4.9 | 4.5 | 4.3 | 4.2 | .0 |
| 190 - 199 | .0 | .0 | .0 | 3.2 | 3.6 | 3.9 | .0 | 5.3 | 4.5 | 4.1 | 4.4 | .0 |
| 200 - 209 | .0 | .0 | .0 | 3.2 | 3.6 | 4.2 | .0 | 5.2 | 4.4 | 4.1 | 4.3 | .0 |
| 210 - 219 | .0 | .0 | .0 | 3.2 | 3.5 | 4.3 | .0 | 5.1 | 4.4 | 4.1 | 4.3 | .0 |
| 220 - 229 | .0 | .0 | .0 | 3.2 | 3.5 | 4.2 | .0 | 5.1 | 4.4 | 4.1 | 4.3 | .0 |
| 230 - 239 | .0 | .0 | .0 | 3.1 | 3.5 | 4.0 | .0 | 5.0 | 4.3 | 4.0 | 4.3 | .0 |
| 240 - 249 | .0 | .0 | .0 | 3.2 | 3.5 | 3.8 | .0 | 4.9 | 4.3 | 4.0 | 4.3 | .0 |
| 250 - 259 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.2 | .0 | 3.9 | .0 |
| 260 - 269 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.2 | .0 | .0 | .0 |
| 270 - 279 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 280 - 289 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 290 - 299 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TC COMPUTE AVG TEMP

LATITUDE = 44 N LONGITUDE = 86 W 1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 8 | 2 | 7 | 0 | 3 | 3 | 8 | 5 | 0 |
| 10 - 19 | 0 | 0 | 0 | 8 | 2 | 7 | 0 | 3 | 3 | 8 | 5 | 0 |
| 20 - 29 | 0 | 0 | 0 | 8 | 2 | 7 | 0 | 3 | 3 | 8 | 5 | 0 |
| 30 - 39 | 0 | 0 | 0 | 6 | 2 | 7 | 0 | 3 | 3 | 7 | 5 | 0 |
| 40 - 49 | 0 | 0 | 0 | 6 | 2 | 6 | 0 | 3 | 3 | 5 | 5 | 0 |
| 50 - 59 | 0 | 0 | 0 | 5 | 2 | 6 | 0 | 3 | 3 | 5 | 4 | 0 |
| 60 - 69 | 0 | 0 | 0 | 5 | 2 | 6 | 0 | 3 | 3 | 5 | 4 | 0 |
| 70 - 79 | 0 | 0 | 0 | 5 | 2 | 6 | 0 | 3 | 3 | 5 | 4 | 0 |
| 80 - 89 | 0 | 0 | 0 | 5 | 2 | 6 | 0 | 3 | 3 | 5 | 4 | 0 |
| 90 - 99 | 0 | 0 | 0 | 5 | 2 | 6 | 0 | 3 | 3 | 5 | 4 | 0 |
| 100 - 109 | 0 | 0 | 0 | 5 | 2 | 6 | 0 | 3 | 3 | 5 | 4 | 0 |
| 110 - 119 | 0 | 0 | 0 | 5 | 2 | 6 | 0 | 3 | 3 | 5 | 4 | 0 |
| 120 - 129 | 0 | 0 | 0 | 5 | 2 | 6 | 0 | 3 | 3 | 5 | 3 | 0 |
| 130 - 139 | 0 | 0 | 0 | 5 | 2 | 6 | 0 | 3 | 3 | 5 | 3 | 0 |
| 140 - 149 | 0 | 0 | 0 | 5 | 2 | 6 | 0 | 3 | 3 | 5 | 3 | 0 |
| 150 - 159 | 0 | 0 | 0 | 5 | 2 | 6 | 0 | 3 | 2 | 5 | 3 | 0 |
| 160 - 169 | 0 | 0 | 0 | 5 | 2 | 6 | 0 | 3 | 2 | 5 | 3 | 0 |
| 170 - 179 | 0 | 0 | 0 | 4 | 2 | 6 | 0 | 3 | 2 | 5 | 3 | 0 |
| 180 - 189 | 0 | 0 | 0 | 3 | 2 | 5 | 0 | 3 | 2 | 3 | 3 | 0 |
| 190 - 199 | 0 | 0 | 0 | 2 | 1 | 4 | 0 | 1 | 2 | 1 | 2 | 0 |
| 200 - 209 | 0 | 0 | 0 | 2 | 1 | 3 | 0 | 1 | 2 | 1 | 2 | 0 |
| 210 - 219 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 1 | 2 | 1 | 2 | 0 |
| 220 - 229 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 1 | 1 | 1 | 2 | 0 |
| 230 - 239 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 1 | 2 | 0 |
| 240 - 249 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 1 | 2 | 0 |
| 250 - 259 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 260 - 269 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 270 - 279 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 280 - 289 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 290 - 299 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 4 (Continued)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 45 N LONGITUDE = 86 W 1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TC COMPUTE AVG TEMP

LATITUDE = 45 N LONGITUDE = 86 W 1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 41 N LONGITUDE = 87 W 1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | 1.6 | 4.7 | 8.8 | 16.2 | .0 | 21.7 | 18.4 | 13.2 | 9.5 | .0 |
| 10 - 19 | .0 | .0 | 1.6 | 4.0 | .0 | 10.5 | .0 | 20.3 | 18.8 | 13.1 | 8.8 | .0 |
| 20 - 29 | .0 | .0 | 2.3 | 4.0 | .0 | 5.8 | .0 | 8.6 | 18.7 | 12.9 | 8.1 | .0 |
| 30 - 39 | .0 | .0 | 2.3 | .0 | .0 | .0 | .0 | .0 | 18.7 | .0 | 6.6 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TC COMPUTE AVG TEMP

LATITUDE = 41 N LONGITUDE = 87 W 1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 6 | 3 | 2 | 10 | 0 | 2 | 2 | 2 | 2 | 0 |
| 10 - 19 | 0 | 0 | 4 | 1 | 0 | 5 | 0 | 1 | 1 | 2 | 1 | 0 |
| 20 - 29 | 0 | 0 | 2 | 1 | 0 | 4 | 0 | 1 | 1 | 1 | 1 | 0 |
| 30 - 39 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 42 N LONGITUDE = 87 W 1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | 2.4 | 3.5 | 5.2 | 11.0 | .0 | 21.4 | 17.9 | 12.8 | 7.5 | 3.9 |
| 10 - 19 | .0 | .0 | 2.3 | 3.6 | 4.5 | 7.8 | .0 | 19.8 | 17.0 | 12.6 | 7.5 | 3.9 |
| 20 - 29 | .0 | .0 | 2.4 | 3.6 | 4.2 | 5.7 | .0 | 10.3 | 15.4 | 10.6 | 7.5 | 4.0 |
| 30 - 39 | .0 | .0 | 2.4 | 3.5 | 4.2 | 4.7 | .0 | 5.1 | 9.0 | 5.0 | 6.8 | 4.0 |
| 40 - 49 | .0 | .0 | 2.5 | 3.5 | 4.2 | 4.4 | .0 | 4.5 | 5.0 | 4.9 | 6.5 | 4.0 |
| 50 - 59 | .0 | .0 | 2.7 | 3.5 | 4.3 | 4.4 | .0 | 4.2 | 4.7 | 4.8 | 6.1 | 4.1 |
| 60 - 69 | .0 | .0 | 2.7 | 3.6 | 4.0 | 4.3 | .0 | 4.0 | 4.6 | 4.5 | 5.7 | 4.1 |
| 70 - 79 | .0 | .0 | 2.8 | 3.9 | 4.0 | 4.2 | .0 | 3.5 | 4.1 | 4.4 | 5.1 | 4.1 |
| 80 - 89 | .0 | .0 | 3.2 | 3.9 | 4.0 | 4.4 | .0 | 3.4 | 4.0 | .0 | 4.4 | 4.1 |
| 90 - 99 | .0 | .0 | 3.2 | 3.8 | 4.0 | 3.9 | .0 | .0 | 3.9 | .0 | 3.3 | 4.2 |
| 100 - 109 | .0 | .0 | 3.3 | .0 | 4.0 | 4.0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 110 - 119 | .0 | .0 | 3.3 | .0 | 4.0 | 4.0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 120 - 129 | .0 | .0 | .0 | .0 | 4.0 | 4.0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 130 - 139 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TC COMPUTE AVG TEMP

LATITUDE = 42 N LONGITUDE = 87 W 1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 6 | 10 | 5 | 12 | 0 | 5 | 3 | 2 | 3 | 1 |
| 10 - 19 | 0 | 0 | 5 | 10 | 4 | 11 | 0 | 5 | 3 | 2 | 3 | 1 |
| 20 - 29 | 0 | 0 | 5 | 10 | 4 | 11 | 0 | 5 | 3 | 2 | 3 | 1 |
| 30 - 39 | 0 | 0 | 5 | 9 | 4 | 10 | 0 | 4 | 3 | 2 | 3 | 1 |
| 40 - 49 | 0 | 0 | 4 | 9 | 4 | 9 | 0 | 4 | 3 | 2 | 2 | 1 |
| 50 - 59 | 0 | 0 | 3 | 9 | 3 | 7 | 0 | 3 | 3 | 2 | 2 | 1 |
| 60 - 69 | 0 | 0 | 3 | 8 | 2 | 6 | 0 | 3 | 3 | 1 | 2 | 1 |
| 70 - 79 | 0 | 0 | 2 | 6 | 1 | 5 | 0 | 2 | 1 | 1 | 2 | 1 |
| 80 - 89 | 0 | 0 | 1 | 5 | 1 | 4 | 0 | 2 | 1 | 0 | 2 | 1 |
| 90 - 99 | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 0 | 1 | 0 | 1 | 1 |
| 100 - 109 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 110 - 119 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 120 - 129 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 130 - 139 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 4 (Continued)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 43 N  LONGITUDE = 87 W  1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | 2.9 | 3.4 | 5.8 | .0 | .0 | .0 | .0 | .0 | 5.6 |
| 10 - 19 | .0 | .0 | .0 | 2.9 | 3.4 | 4.6 | .0 | .0 | .0 | .0 | .0 | 5.8 |
| 20 - 29 | .0 | .0 | .0 | 2.9 | 3.3 | 4.2 | .0 | .0 | .0 | .0 | .0 | 5.8 |
| 30 - 39 | .0 | .0 | .0 | 2.4 | 3.3 | 3.3 | .0 | .0 | .0 | .0 | .0 | 5.8 |
| 40 - 49 | .0 | .0 | .0 | 2.4 | 3.4 | 3.2 | .0 | .0 | .0 | .0 | .0 | 5.8 |
| 50 - 59 | .0 | .0 | .0 | 2.4 | 3.4 | 3.1 | .0 | .0 | .0 | .0 | .0 | 5.8 |
| 60 - 69 | .0 | .0 | .0 | 2.4 | 3.3 | 3.1 | .0 | .0 | .0 | .0 | .0 | 5.5 |
| 70 - 79 | .0 | .0 | .0 | 2.4 | 3.3 | 3.1 | .0 | .0 | .0 | .0 | .0 | 5.[illegible] |
| 80 - 89 | .0 | .0 | .0 | 2.4 | 3.3 | 3.0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | 2.4 | 3.3 | 3.0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 100 - 109 | .0 | .0 | .0 | 2.4 | 3.3 | 2.9 | .0 | .0 | .0 | .0 | .0 | .0 |
| 110 - 119 | .0 | .0 | .0 | 2.4 | 3.3 | 2.8 | .0 | .0 | .0 | .0 | .0 | .0 |
| 120 - 129 | .0 | .0 | .0 | 2.2 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 130 - 139 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 140 - 149 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 150 - 159 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TC COMPUTE AVG TEMP

LATITUDE = 43 N  LONGITUDE = 87 W  1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 5 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 2 |
| 10 - 19 | 0 | 0 | 0 | 5 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 2 |
| 20 - 29 | 0 | 0 | 0 | 5 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 2 |
| 30 - 39 | 0 | 0 | 0 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| 40 - 49 | 0 | 0 | 0 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| 50 - 59 | 0 | 0 | 0 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| 60 - 69 | 0 | 0 | 0 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| 70 - 79 | 0 | 0 | 0 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| 80 - 89 | 0 | 0 | 0 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 100 - 109 | 0 | 0 | 0 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 110 - 119 | 0 | 0 | 0 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 120 - 129 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 130 - 139 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 140 - 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 150 - 159 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 44 N  LONGITUDE = 87 W  1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | 2.6 | 3.5 | 8.9 | .0 | 19.0 | .0 | 11.1 | 7.3 | .0 |
| 10 - 19 | .0 | .0 | .0 | 2.6 | 3.5 | 6.5 | .0 | 12.5 | .0 | 9.6 | 7.1 | .0 |
| 20 - 29 | .0 | .0 | .0 | 2.6 | 3.5 | 5.4 | .0 | 5.8 | .0 | 8.5 | 6.7 | .0 |
| 30 - 39 | .0 | .0 | .0 | 2.9 | 3.4 | 5.3 | .0 | 4.8 | .0 | 6.5 | 6.6 | .0 |
| 40 - 49 | .0 | .0 | .0 | 2.9 | 3.4 | 5.0 | .0 | 4.5 | .0 | 5.9 | 6.5 | .0 |
| 50 - 59 | .0 | .0 | .0 | 2.9 | 3.4 | 4.7 | .0 | 4.5 | .0 | 5.8 | 6.4 | .0 |
| 60 - 69 | .0 | .0 | .0 | 2.9 | 3.4 | 4.5 | .0 | 4.4 | .0 | 5.7 | 6.1 | .0 |
| 70 - 79 | .0 | .0 | .0 | 2.9 | 3.4 | 4.5 | .0 | 4.3 | .0 | 5.6 | 5.8 | .0 |
| 80 - 89 | .0 | .0 | .0 | 2.9 | 3.3 | 4.5 | .0 | 4.3 | .0 | 5.5 | 5.5 | .0 |
| 90 - 99 | .0 | .0 | .0 | 2.9 | 3.3 | 4.4 | .0 | 4.2 | .0 | 5.3 | 5.3 | .0 |
| 100 - 109 | .0 | .0 | .0 | 2.9 | 3.3 | 4.4 | .0 | 4.2 | .0 | 5.2 | 4.9 | .0 |
| 110 - 119 | .0 | .0 | .0 | 2.9 | 3.3 | 4.4 | .0 | 4.1 | .0 | 5.1 | 4.6 | .0 |
| 120 - 129 | .0 | .0 | .0 | 2.9 | 3.3 | 4.4 | .0 | 4.1 | .0 | 5.0 | 4.5 | .0 |
| 130 - 139 | .0 | .0 | .0 | 2.9 | 3.3 | 4.3 | .0 | 4.0 | .0 | 4.8 | 4.4 | .0 |
| 140 - 149 | .0 | .0 | .0 | 2.9 | 3.2 | 4.3 | .0 | 4.0 | .0 | 4.6 | 4.4 | .0 |
| 150 - 159 | .0 | .0 | .0 | 2.9 | 3.2 | 4.3 | .0 | 3.9 | .0 | 4.4 | 4.3 | .0 |
| 160 - 169 | .0 | .0 | .0 | .0 | .0 | 3.4 | .0 | .0 | .0 | .0 | .0 | .0 |
| 170 - 179 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 180 - 189 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 190 - 199 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TC COMPUTE AVG TEMP

LATITUDE = 44 N  LONGITUDE = 87 W  1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 3 | 1 | 4 | 0 | 2 | 0 | 4 | 2 | 0 |
| 10 - 19 | 0 | 0 | 0 | 3 | 1 | 4 | 0 | 2 | 0 | 4 | 2 | 0 |
| 20 - 29 | 0 | 0 | 0 | 3 | 1 | 4 | 0 | 2 | 0 | 4 | 1 | 0 |
| 30 - 39 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 3 | 1 | 0 |
| 40 - 49 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 2 | 1 | 0 |
| 50 - 59 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 2 | 1 | 0 |
| 60 - 69 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 2 | 1 | 0 |
| 70 - 79 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 2 | 1 | 0 |
| 80 - 89 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 2 | 1 | 0 |
| 90 - 99 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 2 | 1 | 0 |
| 100 - 109 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 2 | 1 | 0 |
| 110 - 119 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 2 | 1 | 0 |
| 120 - 129 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 2 | 1 | 0 |
| 130 - 139 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 2 | 1 | 0 |
| 140 - 149 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 2 | 1 | 0 |
| 150 - 159 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 2 | 1 | 0 |
| 160 - 169 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 170 - 179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 - 189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 190 - 199 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 4 (Concluded)

AVERAGE TEMPERATURE BY 10 METER LAYER

LATITUDE = 45 N LONGITUDE = 87 W 1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | .0 | .0 | .0 | .0 | 5.4 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 10 - 19 | .0 | .0 | .0 | .0 | 5.4 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 20 - 29 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 30 - 39 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 40 - 49 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 50 - 59 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 60 - 69 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 70 - 79 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 80 - 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 - 99 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

NUMBER OF BT'S USED TO COMPUTE AVG TEMP

LATITUDE = 45 N LONGITUDE = 87 W 1966

| INTERVAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 9 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 - 19 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 - 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 - 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 - 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 - 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 - 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 - 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 - 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 - 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# THE GRAND RIVER AND ITS PLUME IN LAKE MICHIGAN

John C. Ayers and Ronald Rossmann

The Grand River, discharging to Lake Michigan at Grand Haven, Mich., is Michigan's largest river. Velz and Gannon (1960) give approximately 5,622 square miles as its drainage basin, and Horton and Grunsky (1927, p. 384) indicate a water-year mean flow of about one second-foot per square mile at Grand Rapids, 30 miles above the mouth. The mean annual discharge at the mouth would be, then, about 5,600 cfs.

The river tends to be rather well settled throughout its length and contains the cities of Jackson, Lansing, and Grand Rapids. At each of these cities the river is polluted, with degrees of natural recovery between cities. The lowest 11 miles of the river is navigated commercially in the exploitation of sand and gravel deposits at mile 11. The city of Grand Haven at the river mouth, and the villages of Ferrysburg and Spring Lake just above the mouth are almost contiguous along the swampy banks of the river. Grand Haven has a substantial amount of industry, including a tannery.

The discharge of the river in Lake Michigan is characterized by brown color, high turbidity, and thermal and conductivity differences from the lake water. The survey reported in this paper provided background information about the lower river preparatory to studies of the physical behaviors of the plume of river discharge in the lake.

In this August 1966 survey the lower 11 miles of the river were sampled at three stations, GRS-1 through 3 in Fig. 1, and the turbidity behavior of the river plume in the lake was investigated on one day.

Parameters measured at the river stations were: temperature, turbidity by the Hellige turbidimeter, water transparency and color by Secchi disc, sediment type, benthic organisms by Ponar dredge, suspended particulate matter, and dissolved oxygen by the Alsterberg modification of the Winkler method.

## RESULTS

Grand River water is brown and stained with what appears to be humic decomposition products of plant origin. Turbidity is high, ranging from 34.0 ppm at stations GRS-1 and 2 to 84.5 ppm at 3 ft off the bottom in the densest part of the plume of river effluent where it has just emerged from the breakwaters into the lake. This latter value is obviously due in part to wave-action resuspension of bottom sediment between the breakwaters, for stations GRS-3 just inside the length of breakwaters had only 37.2 ppm turbidity.

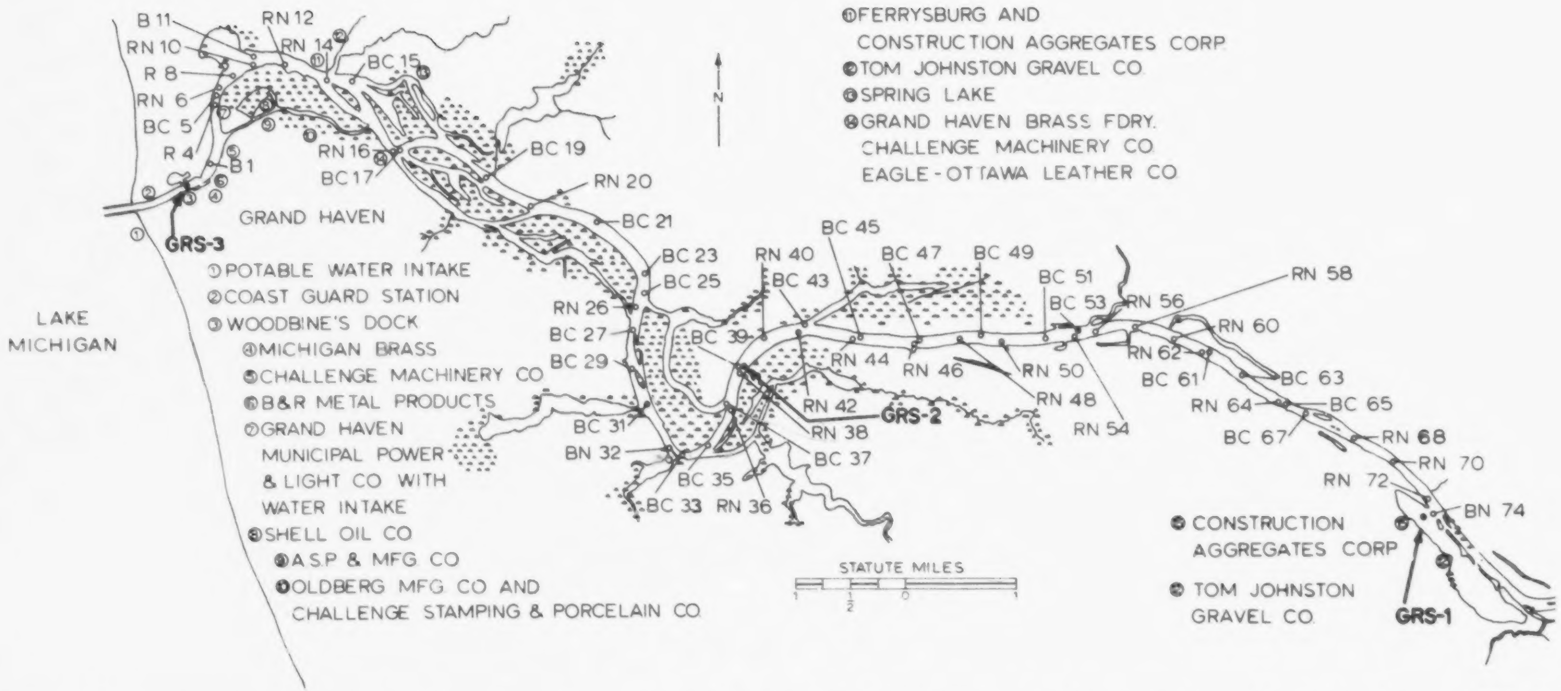
LAKE MICHIGAN
GRAND HAVEN
GRS-3
GRS-2
GRS-1
N
STATUTE MILES
1
1/2
0
1
B 11
RN 10
R 8
RN 6
BC 5
R 4
B1
RN 12
RN 14
BC 15
RN 16
BC 17
BC 19
RN 20
BC 21
BC 23
BC 25
RN 26
BC 27
BC 29
BC 31
BN 32
BC 33
BC 35
RN 36
BC 37
RN 38
BC 39
RN 40
RN 42
BC 43
RN 44
BC 45
RN 46
BC 47
RN 48
BC 49
RN 50
BC 51
BC 53
RN 54
RN 56
RN 58
RN 60
BC 61
RN 62
BC 63
RN 64
BC 65
BC 67
RN 68
RN 70
RN 72
BN 74
① POTABLE WATER INTAKE
② COAST GUARD STATION
③ WOODBINE'S DOCK
④ MICHIGAN BRASS
⑤ CHALLENGE MACHINERY CO
⑥ B&R METAL PRODUCTS
⑦ GRAND HAVEN MUNICIPAL POWER & LIGHT CO WITH WATER INTAKE
⑧ SHELL OIL CO
⑨ A.S.P & MFG CO
⑩ OLDBERG MFG CO AND CHALLENGE STAMPING & PORCELAIN CO
⑪ FERRYSBURG AND CONSTRUCTION AGGREGATES CORP
⑫ TOM JOHNSTON GRAVEL CO
⑬ SPRING LAKE
⑭ GRAND HAVEN BRASS FDRY. CHALLENGE MACHINERY CO EAGLE-OTTAWA LEATHER CO
⑮ CONSTRUCTION AGGREGATES CORP
⑯ TOM JOHNSTON GRAVEL CO

FIG. 1. Orientation chart of the lower Grand River showing locations of the three sampling stations: GRS-1 to 3. Abbreviations for aids to navigation: B or BC, black can buoy; R or RN, red nun buoy; BN, beacon.

Dissolved oxygen was 8.1 mg/l and 97% saturation at station GRS-1, 8.2 mg/l and 98% saturation at GRS-3, and 10.1 mg/l and 120% saturation at GRS-2. The improved condition at GRS-2 is believed to be due to a degree of recovery after the commercial sand and gravel activity at station 1 and before the imposition of the effects of Spring Lake, Ferrysburg and Grand Haven.

At stations 1 and 2 the transparency by 20-centimeter white Secchi disc was 0.3 m. At these stations the water color seen above the disc was dark brown. Some admixture of lake water at station 3 was evidenced by rise of transparency there to 0.5 m and change of water color to brown-green.

Sediment types at the three river stations were: soft black coarse-sandy clay with abundant plant detritus at station 1, grey silty coarse and at station 2, and soft black silty clay with plant detritus and oil at station 3. At station 1 the sediment had a slight organic odor but no smell of hydrogen sulphide. Sediments at station 2 were odorless. Sediments at station 3 smelled of oil.

Table 1 summarizes the results of triplicate samples of the benthic populations at the river stations and the results of triplicate analyses for suspended particulate matter.

TABLE 1. Benthic fauna and suspended particulate matter.

| Station | Amphipods number/m$^2$ | Oligochaetes number/m$^2$ | Tendipedids number/m$^2$ | Others number/m$^2$ | Sups. part. mat. mg/l |
|---|---|---|---|---|---|
| GRS-1 | 0 | 4257 | 86 | 0 | 13.0 |
| GRS-2 | 0 | 552 | 0 | 0 | 13.2 |
| GRS-3 | 43 | 6952 | 172 | 43 | 10.1 |

The benthic organisms were predominantly oligochaete worms. These tolerant organisms were present in numbers sufficiently high to indicate some eutrophication of the river, but not in numbers sufficient to indicate a state of pollution.

Amphipods and "others" (mostly leeches) were present only in station 3 and in small numbers. Their presence at station 3 probably is an indication of dilution by lake water. Suspended particulate matter was quite uniform in the two upriver stations but fell somewhat at station 3, again indicating dilution of the river mouth by lake water.

Conductivity (specific conductance at 25°C) determinations in the river in May 1966 had shown 569 µmhos/cm$^3$ at a station off Spring Lake and 550 µmhos/cm$^3$ at the end of the breakwaters. Lake water conductivity was 277 µmhos/cm$^3$. Again dilution by lake water at the river mouth was indicated.

Water temperatures at the river stations ranged from 23.0 to 23.2°C in the mid-August survey. At this time the alongshore lake water was varying between 18 and 19°C.

River-water characteristics that appear well suited for use in tracing the dispersion of the river effluent in the lake are: water color, turbidity, conductivity and water temperature.

## A STUDY OF THE RIVER PLUME

On 18 August 1966, with the river running northward from the ends of the breakwaters as the result of previous southwest wind, and being opposed by a newly risen north wind, the distribution of turbidity in the brown plume of river-water in the lake was determined.

Surface samples and samples at 3 ft off the bottom were taken by plastic Van Dorn bottle for Hellige turbidity analyses. At a mile north of the breakwaters all visual evidence of the river plume was lost. Two parallel lines of turbidity samples in the plume were taken, at three-quarters of a mile and at 100 yards north of the breakwaters. Figures 2 and 3 show the locations of the sampling stations A through H. Stations A and G were in clear blue-green lake water outside the plume and station H was between the breakwaters in the visibly densest part of the brown river flow.

Turbidity values obtained were reduced to approximate percent of river water by considering that each volume of observed turbidity was comprised of x fraction of a volume of the highest turbidity combined with (1 - x) volume of the lowest turbidity:

$$1\ T_{obs} = (1 - x)\ T_{lowest} + x\ T_{highest}$$

where 84.5 ppm near the bottom at station B was the highest obtained value and 25 ppm at the surface at station G was the lowest value obtained. There are two sources of uncertainty in these highest and lowest values: 84.5 ppm must have contained some resuspended bottom sediment, but the same wind that resuspended it was blowing throughout the survey; 25.0 ppm was a value obtained close to the river plume and it must have contained an unknown but small fraction of river water.

Despite these limitations the technique shows real promise as a means of following the relative dispersion of the river plume in the lake.

The data obtained are shown in Table 2.

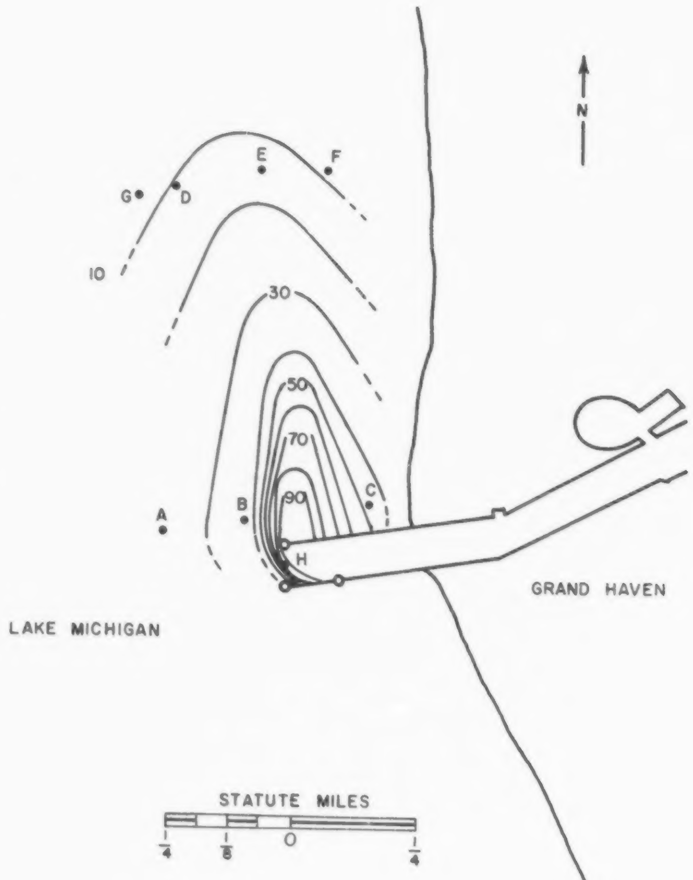
N
G
D
E
F
10
30
50
70
90
A
B
C
H
GRAND HAVEN
LAKE MICHIGAN
STATUTE MILES
1/4
1/8
0
1/4

FIG. 2. Percentage of river water in the surface of the Grand River plume in Lake Michigan.

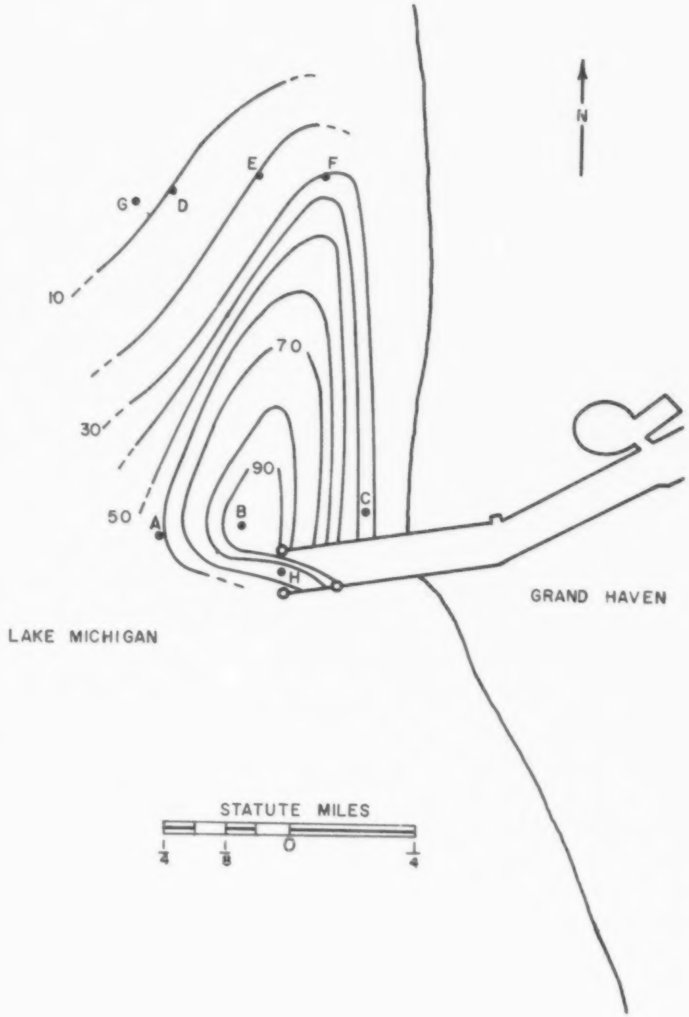
N
G
D
E
F
10
30
50
70
90
A
B
C
H
GRAND HAVEN
LAKE MICHIGAN
STATUTE MILES
1/4
1/8
0
1/4

FIG. 3. Percentage of river water at 3 ft off the bottom in the Grand River plume in Lake Michigan.

TABLE 2. Turbidities and percent of river water in plume.

| Station | Surface | | Three feet off bottom | |
|---|---|---|---|---|
| | Turbidity ppm | % of river water | Turbidity ppm | % of river water |
| A | 35.5 | 17.6 | 59.0 | 58.2 |
| B | 48.2 | 39.0 | 84.5 | 100.0 |
| C | 52.2 | 45.7 | 45.1 | 34.5 |
| D | 31.5 | 10.3 | 31.5 | 10.3 |
| E | 33.5 | 14.3 | 36.0 | 18.5 |
| F | 30.0 | 8.4 | 42.2 | 28.9 |
| G | 25.0 | 0 | 27.5 | 4.3 |
| H | 72.0 | 79.0 | 68.5 | 73.2 |

The approximate distributions of percentage or river water at the surface and at 3 ft off bottom are shown in Figs. 2 and 3, respectively. Comparison of the two figures shows that each isopleth reaches considerably farther north in the subsurface water than it does in the surface water. This might be taken to be underflowing by the river water, but it is more probable that it only reflects greater dilution in the surface water as the current generated by the north wind opposed the northward flow of the river plume.

Also evident in the two figures are the facts that the dilution of the subsurface river water was going on at a slower rate than that of the surface water, and that the subsurface portion of the plume had a definite tendency to turn toward the beach.

This trial survey indicates that study of the dispersal of river plumes may provide basic insight into the behaviors of alongshore waters of the lake.

## REFERENCES

HORTON, R. E. and C. E. GRUNSKY. 1927. Hydrology of the Great Lakes. Part III - Appendix II of Report of the Engineering Board of Review of the Sanitary District of Chicago on the Lake Lowering Controversy and a Program of Remedial Measures. Sanitary District of Chicago, Chicago, Ill. 432 p., 142 tables, 73 figs.

VELZ, C. J. and J. J. GANNON. 1960. Drought flow characteristics of Michigan Streams. Dept. of Environmental Health, The University of Michigan in cooperation with The Michigan Water Resources Commission. 771 p., 249 tables, 198 figs.

# STUDIES OF MILWAUKEE HARBOR AND EMBAYMENT

John C. Ayers and Joseph C. K. Huang

## INTRODUCTION

The city of Milwaukee, Wis., has for years discharged the effluent from its Jones Island Sewage Treatment Plant into Milwaukee Harbor immediately beside the mouth of the polluted Milwaukee River. The harbor of Milwaukee is an artificial harbor formed by man-made breakwaters in what was naturally a large shallow indentation of the shoreline. The river effluent and the effluent of the Jones Island treatment plant are discharged at the shoreline inside the breakwaters. The limited confines of the harbor and the discharge of effluents directly into the harbor suggested that the harbor might be being forced to function as a sewage lagoon.

The limited confines of the harbor and its polluted condition made it a suitable place in which to determine the levels which some of our routine open-lake measurements could attain in polluted water. This was needed for better definition of when high levels of these parameters in inshore open-lake situations should be interpreted as showing polluted water.

Nearly every harbor on Lake Michigan is polluted, but in no other that we know of are the pollution sources so clean-cut. Other harbors have limited confines backed by polluted and weakly-flowing rivers, but few put sewage effluents directly into their harbors. Other polluted harbors have domestic water intakes adjacent to them, but no other that we know of has domestic water intakes on both sides of the polluted harbor.

That raw-water quality at the Milwaukee intakes is reputed to be good was, under these conditions, an enigma. It suggested either successful function of Milwaukee Harbor as a sewage lagoon, or that there was effective dilution and dispersion between the entrances to the harbor and the water intakes.

The present study was undertaken with the threefold goal of looking for diminishing-lakeward gradients that might indicate a sewage lagoon function of the harbor, of ascertaining the polluted-water levels of certain biological parameters difficult to interpret, and of determining (if possible) why good-quality raw water is obtained from both sides of a polluted harbor.

In June 1964 the R/V INLAND SEAS carried out a preliminary survey of water quality and sediment types in the harbor and the embayment. This preliminary survey showed definite deterioration of the harbor water and harbor sediments. Further study appeared justified.

The bottom sediment data of the preliminary survey were combined with those of the present study and are shown in a later figure.

## PROCEDURES

In July 1965 the R/V MYSIS carried out a detailed survey of Milwaukee Harbor and the adjoining embayment. Seventy-four stations were sampled between 21 and 28 July. Twenty-nine of these stations were inside the breakwaters and 45 were in the embayment outside. These sampling stations are shown in Fig. 1.

At each single-circled station three benthos samples were taken by Ponar dredge. The sediments of these samples were closely examined. If the sediment was black or very dark grey, or if the sediment had an oily smell, an additional sample was taken and quick-frozen for loss-on-ignition analysis. Water transparency was measured by Secchi disc, and water color over the Secchi disc was recorded in descriptive terms. Water temperature at surface, 3 m, and 3 m above bottom (in depths less than 32 ft the last was not taken) was measured by thermistor. _In situ_ conductivity was measured at the same depths.

Double-circled stations were sampled the same as the single-circled stations, but an extra sediment sample for ignition loss was taken and a single cast of Nansen bottles for chemical analyses was taken.

The triple-circled stations were sampled the same as the double-circled stations, with the addition of three Nansen bottle casts for triplicate samples of seston, and with four No. 5 net and one No. 20 net oblique plankton hauls from bottom to surface. Three hundred ml raw water samples from upper and lower levels were preserved with Utermohl's iodine solution and kept for phytoplankton study.

Benthos samples were washed through a 0.5-mm sieving device and the benthic organisms preserved with neutral formalin. In the laboratory ashore, the benthic organisms were sorted and counted into the major taxonomic groups: Amphipoda, Oligochaeta, Sphaeriidae, Tendipedidae, and minor constituents which included leeches, gastropods, etc. The organisms from each sample were recombined in a procelain crucible, oven-dried over night at 60°C, weighed, then ashed to constant weight in a muffle furnace at 600°C. Dry weight minus ash weight gave ashfree weight. All data were converted to grams per square meter. Not all the benthos samples were ashed.

Chemical analyses performed were: dissolved oxygen by the Alsterberg modification of the Winkler method, pH by the Beckman glass electrode, sulphide by the colorimetric method (all according to "Standard Methods for the Examination of Water and Wastewater," 11th edition), and turbidity by the Hellige turbidimeter.

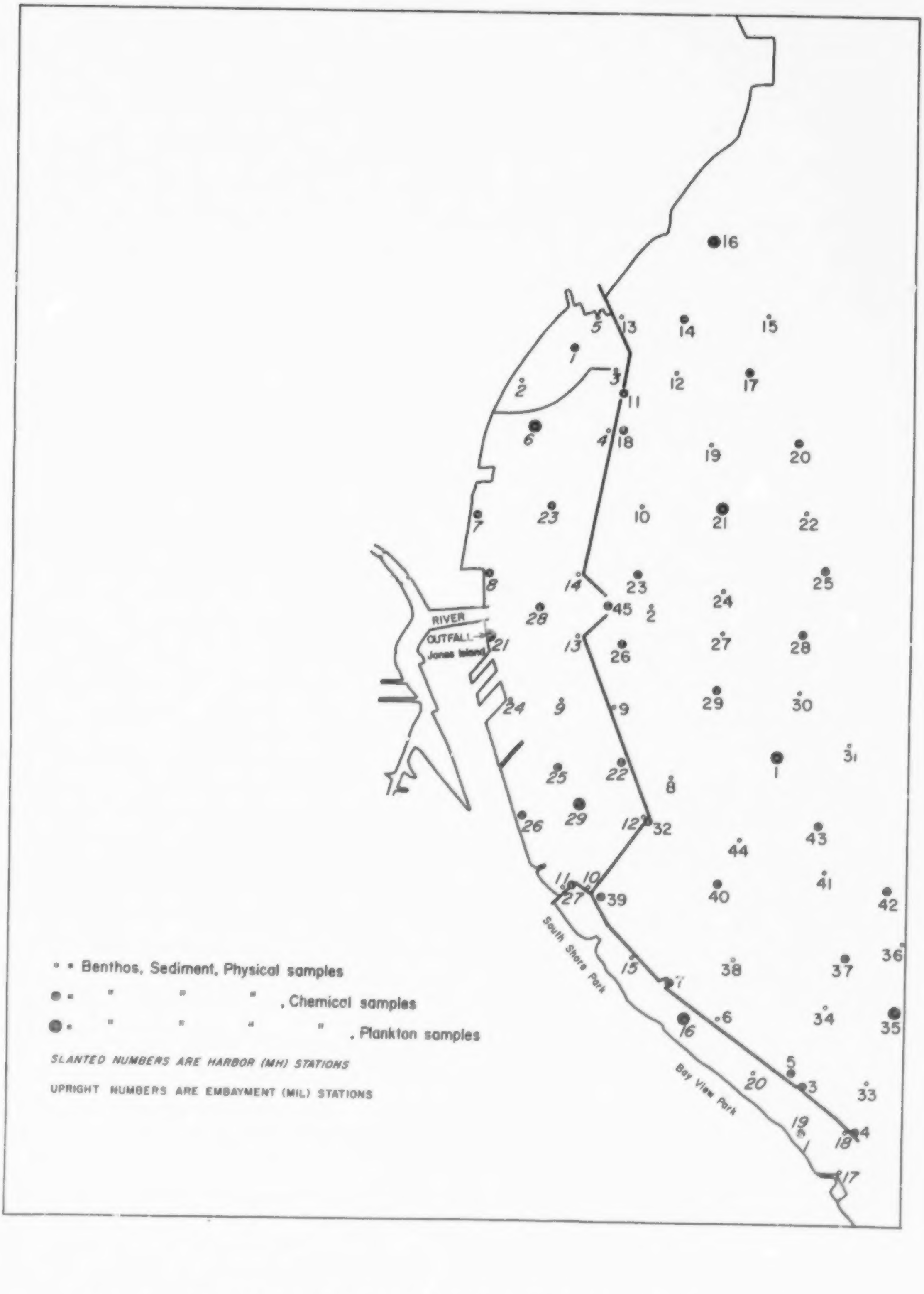
RIVER
OUTFALL
Jones Island
South Shore Park
Bay View Park
∘ = Benthos, Sediment, Physical samples
● = " " " , Chemical samples
● = " " " " , Plankton samples
SLANTED NUMBERS ARE HARBOR (MH) STATIONS
UPRIGHT NUMBERS ARE EMBAYMENT (MIL) STATIONS

FIG. 1. Sampling stations, Milwaukee Harbor, and embayment.

Frozen sediment samples were dried to constant weight at 60°C, and ashed in the muffle furnace at 600°C. Triplicate subsamples were averaged.

From each of the triplicate Nansen bottle casts a 300-ml upper-water sample (150 ml each from 0 and 3 m) and a 300-ml lower-water sample (if taken) were each filtered through a Millipore filter. Each filter was desiccator-dried, weighed, and ashed. Dry weight minus ash weight gave ashfree weight of seston (suspended particulate matter). The values given are averages of triplicates.

Three of the No. 5 plankton net hauls were filtered through a Whatman filter, dried, weighed, and ashed. Dry weight minus ash weight gave ashfree weight. Values given are averages of triplicates. The fourth haul was formalinized and saved for microscopic examination. The No. 20 net haul was formalinized and saved for microscopic examination.

Figure 1 indicates by slanted numbers the sampling stations in the harbor which bear the prefix MH (Milwaukee Harbor), i.e., MH-29, and by upright numbers the sampling stations in the embayment outside the breakwaters where each station has the prefix MIL, i.e., MIL-29.

The five entrances to the harbor are passages through the breakwaters. North Entrance is near the northern end of the breakwaters and has station MIL-11 in it; the main entrance is opposite the river mouth and station MIL-45 is in it; South Entrance is at the southeastward angle of the breakwater and contains station MIL-32; two unnamed entrances in the southward extension of the breakwaters are occupied by stations MIL-7 and MIL-3.

The curved internal bulkhead in the north end of the harbor opposite North Entrance was just being completed at the time of the MYSIS survey; it is considered not to have been in existence long enough to have modified the distribution of sediment types or benthic organisms. Designed to protect small boats at anchorages and in a marina in the north end of the harbor, this bulkhead appears also to be well designed to promote the stagnation of the waters it shelters.

For reasons of bulk, the station data are not presented here. They are available at the Great Lakes Research Division.

## RESULTS

### WATER COLOR

As seen over the white Secchi disc, the dominant color of the water in Milwaukee Harbor was brown. Dark brown or dark grey-brown waters enter the harbor from the Milwaukee River and from the Jones Island Sewage Treatment plant.

With increasing distance from the sources, these waters become progressively diluted with lake water entering through the harbor entrances. Somewhat poorer circulation in the north end of the harbor was indicated by the fact that water color there became diluted to only a light brown whereas in the south end of the harbor and along the inner sides of the breakwaters brown-green water indicative of intermixed lake water was common. The inner bulkhead in the north end of the harbor may be expected to further interfere with circulation in the north end, and further deterioration of water quality and color in that part of the harbor is probable.

Behind the breakwaters protecting South Shore Park and Bay View Park, a substantial intermixture of harbor water was shown by brown-green water color there.

Under offshore winds, broad streaks of discolored harbor water are blown out through the passages in the breakwaters, and balancing subsurface flows of lake water into the harbor take place in the depths of the passages. Under onshore winds, surface lake water enters the harbor through the passages, and subsurface outward flow of harbor water takes place in the depths of the passages. At station MIL-8 under a northeast breeze the ship's propeller kicked up brown harbor water through a surface layer of blue-green lake water.

In the embayment outside the breakwaters, brown or brown-green water was frequently found, its location dependent upon the day's wind, but by about a mile off the breakwaters the blue-green water typical of alongshore lake water was dominant.

## SECCHI DISC TRANSPARENCY

Secchi disc transparency, as used here, is the depth (to the meter and estimated tenth-meter) where the 20-cm white Secchi disc disappears from sight. Since the disc as used has some ability to reach through shallow surface flows and to integrate them to a degree with subsurface flows, we have contoured in Fig. 2 the Secchi disc transparencies obtained during the survey. Transparencies in the embayment outside the breakwaters were of primary interest, and along the right side of the figure we indicate the dominant winds under which the stations in the embayment were occupied.

We call attention to the facts that the stations in the north end of the embayment were taken under wind from the north that was pushing blue-green lake water into the region, and that stations in the southern part were under northwest winds which were pushing harbor water out into the area. Stations in the central protion of the embayment were under northeast wind that was compressing against the breakwater any transparency effect of damaged water escaping from the harbor. Transparency effects of turbid harbor water extending northeastward from the harbor entrances in the central and northern portions, while high trans-

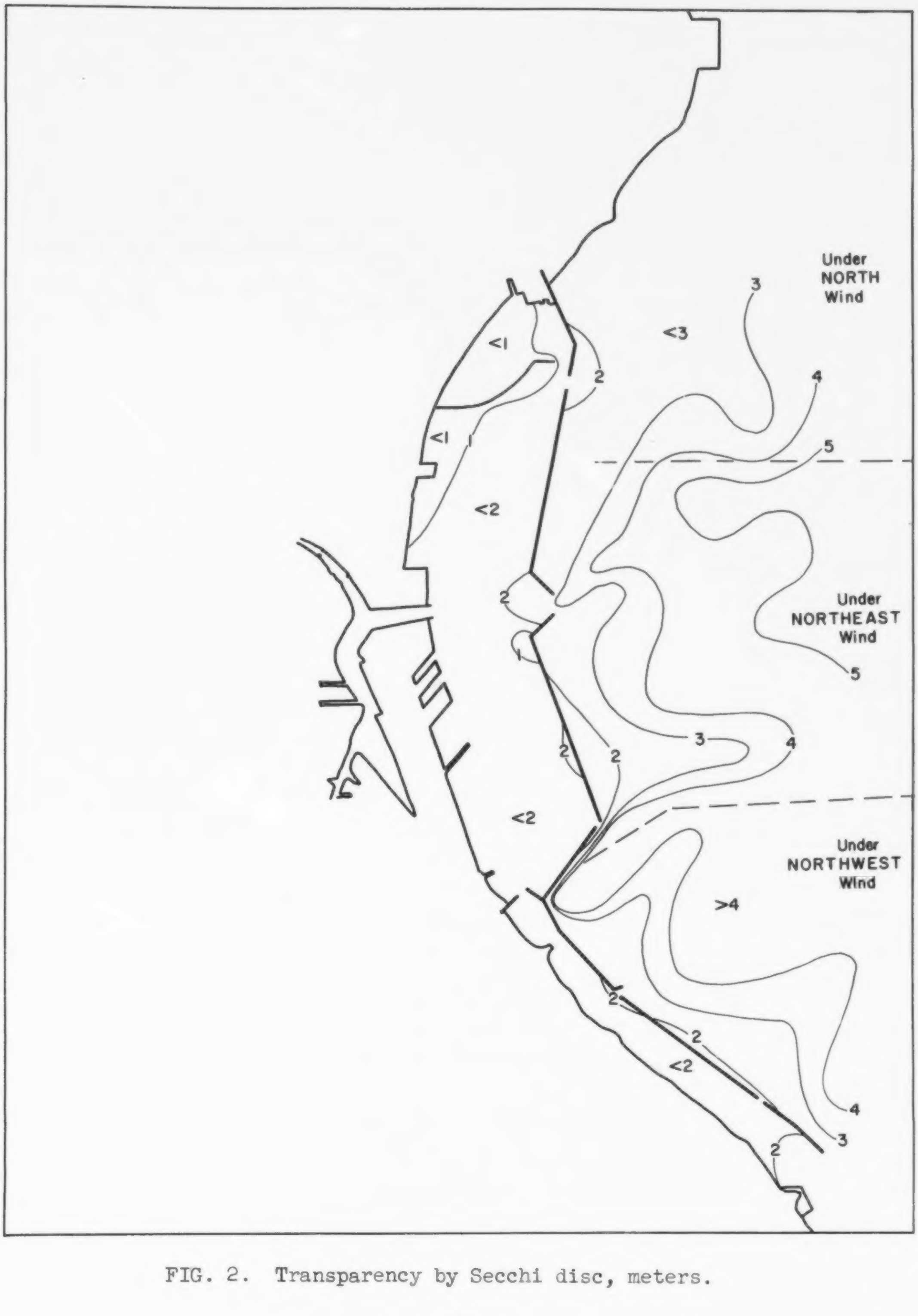
Under
NORTH
Wind
3
<3
<1
2
4
<1
1
5
<2
2
Under
NORTHEAST
Wind
1
5
2
2
3
4
<2
Under
NORTHWEST
Wind
>4
2
2
<2
4
3
2

FIG. 2. Transparency by Secchi disc, meters.

parency water dominated the southern portion, were all obtained under winds specifically adverse to these conditions. They are consequently regarded as strong characteristics of the embayment.

Transparencies of less than 3 m extended northeastward from all three entrances of the main harbor. To some extent the same was true for the two openings in the south extension of the breakwaters. The northward and eastward extension of visible effects of harbor water, and the dominance of clear lake water in the south portion are together taken to indicate a preeminent south-to-north lake current through the embayment. It is further confirmed by several aspects of the distribution of benthic organisms found by the present study and discussed later.

## pH

pH values at stations within the harbor ranged from 7.5 to 8.6, with an average of 8.05. Of the 23 measurements, 12 were less than 8.0. At stations MH-6, MH-7, MH-8, MH-21, and MH-24 along the shoreline the pH values at all depths were less than 8.0. At MH-22 and MH-23 subsurface values less than 8.0 underlay surface values of 8.3 and 8.5.

The least pH value found in the harbor was at station MH-21 at the outfall of the Jones Island sewage treatment plant; here the surface value was 7.5 and the value at 3 m was 7.6. The maximum value found in the harbor was 8.6 at the surface in station MH-1.

In the embayment, pH ranged from 7.7 to 8.7, with an average value of 8.35. Of 59 total measurements only three were below 8.0; these occurred at stations MIL-5 (3 m), MIL-17 (8 m), and MIL-32 (8 m). These values were, respectively, 7.9, 7.9, and 7.7. Station MIL-5 was on a sewage outfall from Bay View Park. Station MIL-32 was in South Entrance. MIL-17 lay northeast of the main entrance.

## TURBIDITY

Within the harbor, turbidity ranged from 1.1 to 9.1 mg/l (ppm on the Hellige $SiO_2$ scale). The maximum value occurred at the surface at station MH-8 near shore north of the river mouth. The minimum value was found in surface water of station MH-23. Highest turbidities, 4.5 to 9.1, occurred at stations along the shore and lower values of 2.0 to 3.6 along the breakwater of the main harbor. Behind the southward breakwater extension in front of South Shore Park and Bay View Park, turbidities ranged from 3.6 to 4.4. The average of all turbidity values from harbor stations was 4.8.

At stations in the embayment, turbidities ranged from 0.75 to 12.2, though the 12.2 value was at the bottom at station MIL-5 and over the outfall of the sewer from Bay View Park. The highest legitimate embayment turbidity was 10.7 at the surface in station MIL-7 in the breakwater passage off South Shore Park; we entertain the possibility that this value may be a result of the concentration of boats at the South Shore Yacht Club. The Yacht Club is on the point of land protruding lakeward in South Shore Park.

The mean of all turbidity measurements in the embayment was 3.06. Surface values at nearly all the embayment stations south of the main harbor entrance (excluding stations in the breakwater passages) were less than 2.0 mg/l. Surface values at nearly all the stations north of the main entrance were more than 2.0. Bottom turbidities approaching the levels of those in the harbor were present in many of the embayment stations. These are considered most likely to be resuspensions of bottom sediment by current.

## CONDUCTIVITY

Conductivity (25°C) at stations within the harbor ranged from 287 $\mu$mho/cm$^3$ at stations MH-17 and MH-18 at the extreme southern end of the southward extension of the breakwater to 443 at 3 m in station MH-24. With the exceptions of stations MH-17 through MH-20 and at 3 m off bottom at MH-12 which were in the 200's, and individual-depth values at MH-9 (0 m), 0 and 3 m in station MH-13, 0 m in MH-21, and 3 m in MH-24 which were in the 400's, all the 56 conductivity values from harbor stations were between 300 and 400 $\mu$mho/cm$^3$. The grand average of all conductivity values within the harbor was 347 $\mu$mho/cm$^3$.

At embayment stations conductivity ranged from 260 $\mu$mho/cm$^3$ on the surface in MIL-19 to 330 $\mu$mho/cm$^3$ at the surface in MIL-11. The overwhelming preponderance (96) of the 105 samples from embayment stations were in the 200's. Of these 96, 54 were in the 270's, and the overall average of embayment values was 279 $\mu$mho/cm$^3$.

## DISSOLVED OXYGEN

Dissolved oxygen at stations within the harbor averaged 9.4 mg/l. The $O_2$ minimum of 5.4 mg/l was at 3 m in station MH-21 at the sewage plant outfall. Maximum content of oxygen was found at the surface in station MH-26; the value here was 13.3 mg/l.

At stations in the embayment, the average value of dissolved oxygen was 10.4 mg/l. Minimum oxygen content in embayment stations was 5.4 mg/l at 8 m at station 32 in South Entrance. This low value was evidently due to escaping harbor water. The lowest legitimate embayment DO value was 9.1 mg/l at the surface in station MIL-1. Maximum oxygen content was 12.8 mg/l at the surface in station MIL-18.

## SULPHIDE

Reasoning that reducing conditions in anaerobic portions of the rivers and in the sewers and sewage treatment plant might produce sulphide salts that might serve as tracers, we included sulphide analyses on water samples. Sulphide analyses were strictly experimental, for we expected rather quick oxidation to the sulphate condition when sulphides reached oxygenated waters of the harbor and lake. Sulphides, however, proved to last long enough to be useful tracers throughout the region surveyed. The distribution of sulphides is shown in Fig. 3. All values at each station were averaged.

The lowest mean value of sulphide in the harbor was at station MH-6 (180 mg/l); highest value in the harbor was at station MH-27 where the average was 520 mg/l. Station MH-26 with 488 and station MH-16 with 426 were next highest. Since these stations are away from the sewage treatment plant and the river mouth, but near the South Shore Yacht Club, we are inclined to attribute the high values to local origin. Mean value of sulphide from all stations in the harbor was 315 mg/l.

From the river mouth and the treatment plant outfall a broad belt of greater-than-300 mg/l occupied much of the harbor, and extensions of it reached lakeward to the north and east through the main harbor entrance and North Entrance. Sulphide levels of less than 300 extended around the extreme southern end of the breakwater and turned north from there.

Lowest levels of sulphide in the embayment were less than 200 mg/l. Considerable areas of water with this content were pushed into the northern and central portions of the embayment by the north and northeast winds of the days when these stations were taken.

As was the case with transparencies, the indicated northward and eastward movements of harbor water under north wind in the northern third, under northeast wind in the central third, and under northwest wind in the southern third, are taken to indicate a dominant south to north current through the embayment.

## BOTTOM SEDIMENTS

The distribution of surficial bottom sediments in Milwaukee Harbor and embayment is presented in Fig. 4. This sediment chart combines the findings by the R/V INLAND SEAS during a preliminary survey in 1964 with those of the present survey by the R/V MYSIS. Within the harbor, organic sediments were found at almost all stations, and organics extended southward past station MH-15 south of the South Shore Yacht Club. Harbor sediments averaged 9.45% loss-on-ignition, with a maximum value of 16.1% immediately outside the outfall of the Jones Island Sewage Treatment Plant. Hair and seeds were abundant in this sediment.

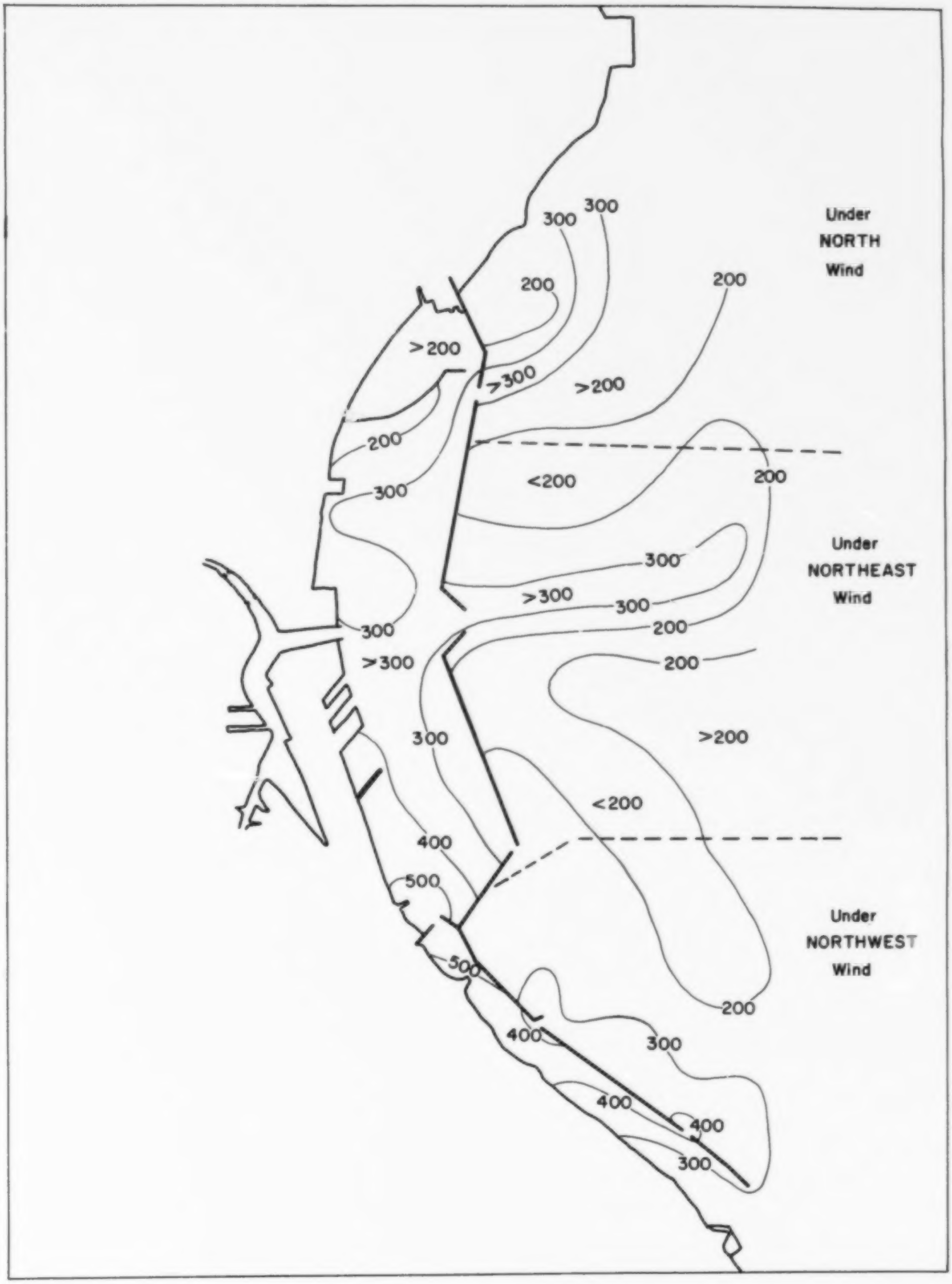
300
300
Under
NORTH
Wind
200
200
>200
>300
>200
200
<200
200
300
Under
NORTHEAST
Wind
300
>300
300
200
300
>300
200
300
>200
<200
400
500
Under
NORTHWEST
Wind
500
200
400
300
400
400
300

FIG. 3. Sulphide, mg/l.

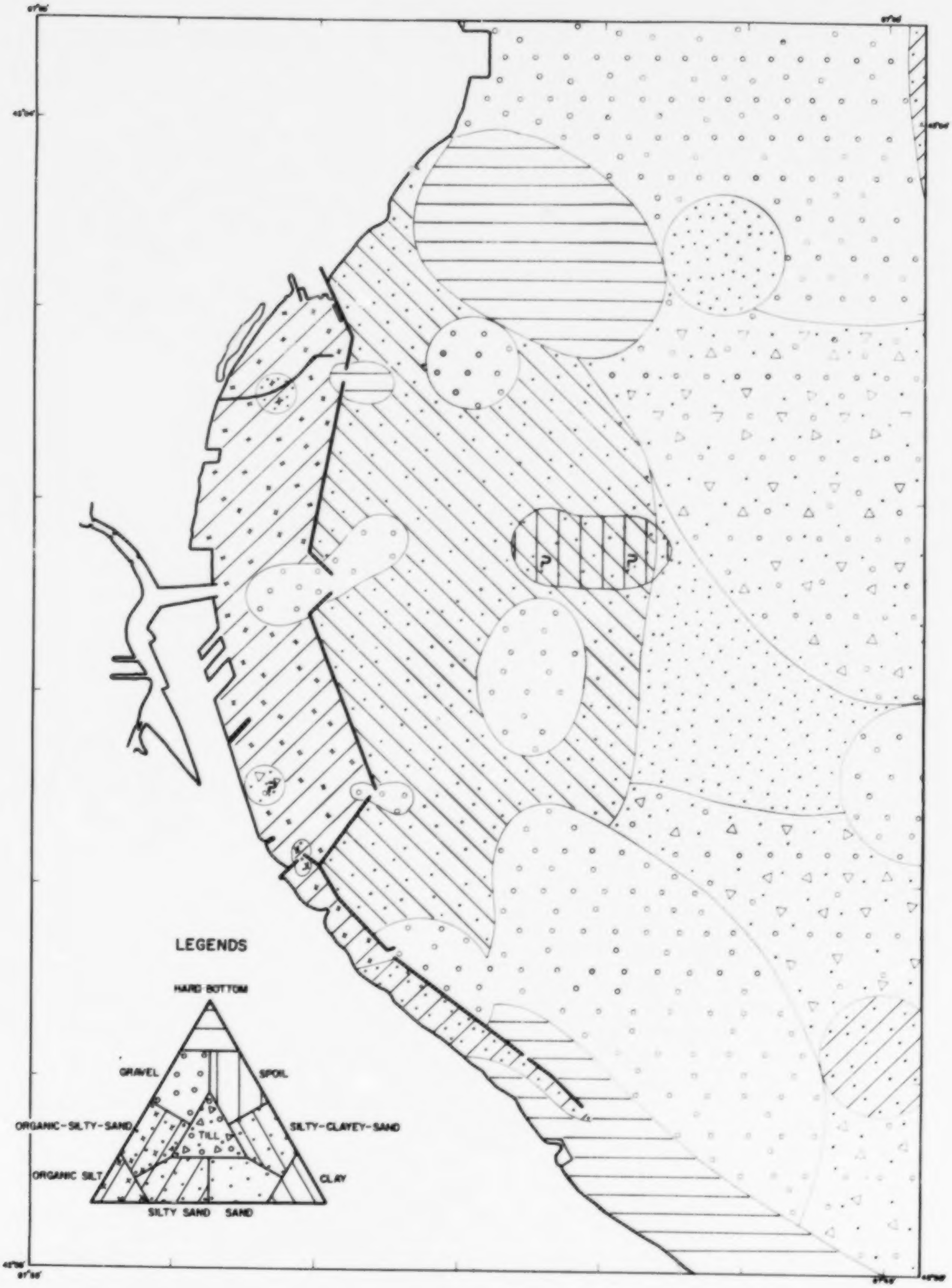
LEGENDS
HARD BOTTOM
GRAVEL
SPOIL
ORGANIC-SILTY-SAND
SILTY-CLAYEY-SAND
TILL
ORGANIC SILT
CLAY
SILTY SAND
SAND

FIG. 4. Bottom sediments of Milwaukee Harbor.

Within the main part of the harbor and in the southward harbor extension to a point south of the South Shore Yacht Club the dominant surface sediment of the bottom was an organic silt which varied in thickness from half an inch to more than the 6-in. penetration of the grab-sampler.

South of station MH-15 and extending past the front of Bay View Park the sediment behind the breakwater was silty sand, except at the south end of the breakwater where hard clay bottom began and extended along the shore southward out of the survey area. Small areas of organic silty sand were found in the north and south ends of the main harbor. A small area of questionable till was present in the southwest corner of the main harbor.

Hard bottom was present in each of the passages throughout the breakwaters. In most cases these hard bottoms were of solid clay with varying overlays of gravel. Current action apparently winnows out all the loose finer sizes in these passages.

Outside the breakwaters there was an extensive area of silty clayey sand. Its distribution around the breakwater passages, and the virtual absence of such sediment in the rest of the embayment, suggest that the silt fraction is largely a contribution from the harbor. Outside the area of silty clayey sand, gravel and till are the dominant surficial sediments of the embayment.

Off the main harbor entrance was a limited area suspected of containing dredging spoil.

## BENTHOS

The dominant organisms in the harbor were the pollution-tolerant sludge-worms. Figure 5 shows the distribution of benthos populations found. Every station inside the breakwaters had a density of worms of 10,000-50,000 or more per square meter, and over most of the main harbor the numbers ranged from 50,000 to over 300,000/m$^2$. Maximum numbers (383,044/m$^2$) were found in the shelter of the breakwater inside the north side of the main entrance to the harbor. Least numbers in the main harbor were inside the North Entrance where 10,000-50,000/m$^2$ were found. Similar numbers were present at a single station each in the south-west corner of the main harbor and at the extreme south end of the breakwater off Bay View Park. At the main harbor entrance and the Southeast Entrance reduced numbers of organisms were present, probably in response to the current-swept and less suitable sediment types in those locations.

In the embayment outside the breakwaters worms in concentrations of 50,000-100,000/m$^2$ were found in a limited area outside the north side of the main harbor entrance. Three areas of 10,000-50,000/m$^2$ were present along the outside of the main harbor breakwaters. A small area lay outside the north side of the main entrance; another was south and east of the North Entrance; the third was northeast the South Entrance. A single station northeast of North Entrance also contained these numbers.

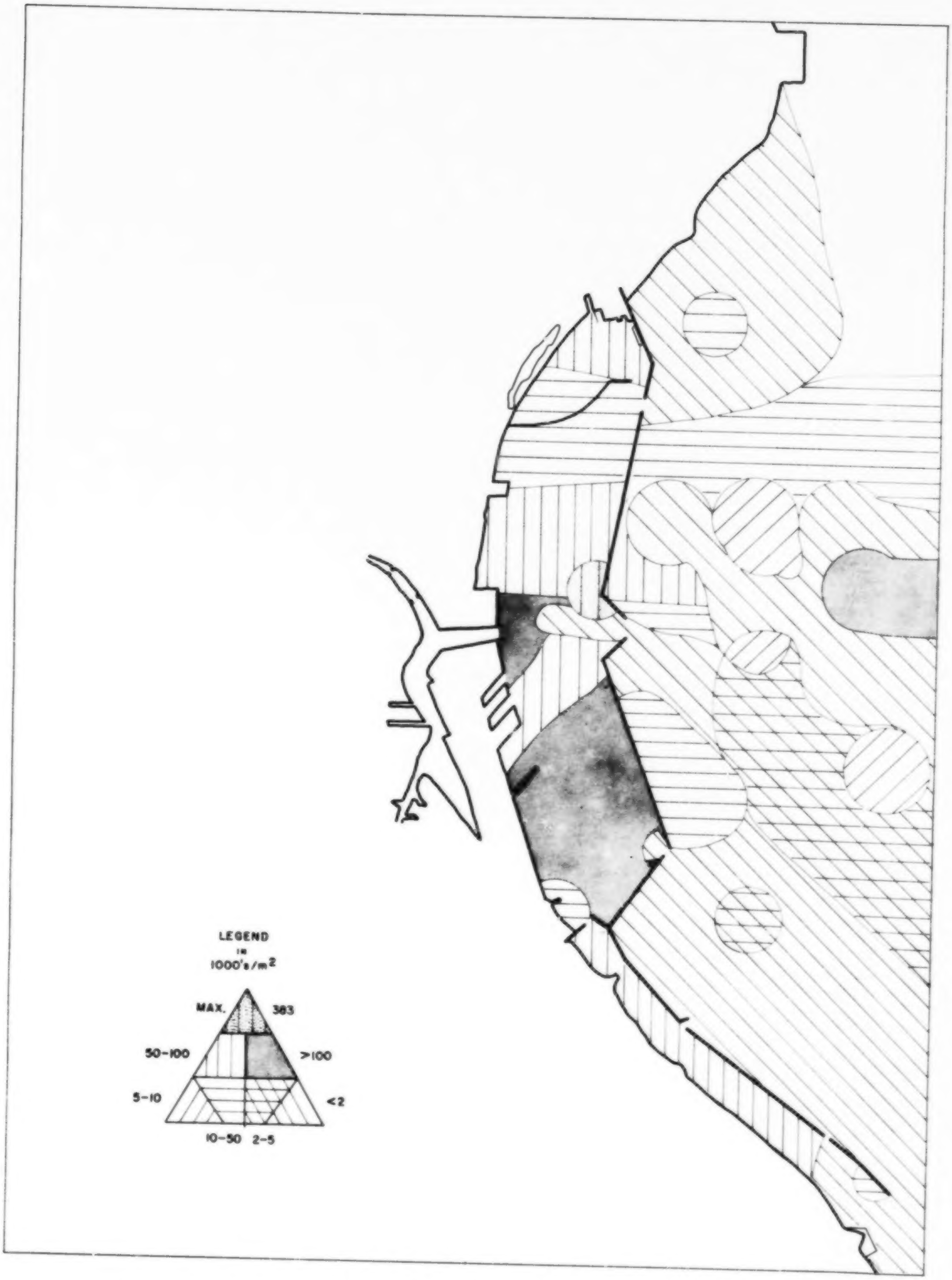
LEGEND
IN
1000's/m²
MAX.
383
50-100
>100
5-10
<2
10-50
2-5

FIG. 5. Distribution of benthos in Milwaukee Harbor (numbers in thousands per square meter).

At two stations about a mile off the main entrance to the harbor, populations in excess of 100,0000/m$^2$ were found. The reason for this concentration is not known, though its position suggests a spoil-dumping ground not recognized in our sediment surveys.

Over the major portion of the embayment benthos populations ranged from less than 2,000 to 10,000 organisms per square meter. Except for the possible spoil area off the main entrance, the locations of high populations suggest approximately northeastward movement of enriched water from the main harbor as the long-term mean water movement.

Thirteen benthos samples, eight from stations in the harbor and five from embayment stations, were ashed to obtain the ashfree dry weight of organism tissue present. Within the harbor the weight of benthos tissue ranged from 0.3 gm/m$^2$ at station MH-26 in unsuitable till bottom to 74.1 gm/m$^2$ at station MH-14 just inside the main entrance. At the outfall of the Jones Island sewage plant there was 15.8 gm/m$^2$. The range in embayment stations was from 0.5 gm/m$^2$ at MIL-22 to 14.2 gm/m$^2$ at MIL-2 directly outside the main harbor entrance. The average weight of tissue at the eight harbor stations was 31.7 gm/m$^2$; in the embayment stations the average was 5.0 gm/m$^2$.

## OLIGOCHAETES

Except for minor variations, the pattern of oligochaete distribution was the same as that of total benthos. Figure 6 gives the distribution of oligochaetes in thousands per square meter.

The oligochaetes heavily dominated the benthos of the entire survey area. Within the main harbor there are only minor variations in the placement of the limits of population density. Again, the maximum numbers were found inside the harbor hear the north side of the main entrance. Again, reduced numbers were found in the three entrances into the main harbor, reflecting the harder current-swept sediments there. Again, the heavier population densities lay northeast of the openings in the breakwaters. Again, the suspected spoil area outside the main harbor entrance was reflected by heavy population.

## AMPHIPODS

The distribution of the clean-water-loving amphipods (Fig. 7) was markedly different from that of total benthos and of oligochaetes. Near the extreme north and south ends of the area inside the breakwaters there were small regions wherein there were 50-500 amphipods/m$^2$; at one station on the south side of the main harbor entrance amphipods attained to this degree of abundance. Throughout the rest of the harbor the level of amphipod population was at less than 50/m$^2$; at most of these stations there were no amphipods at all.

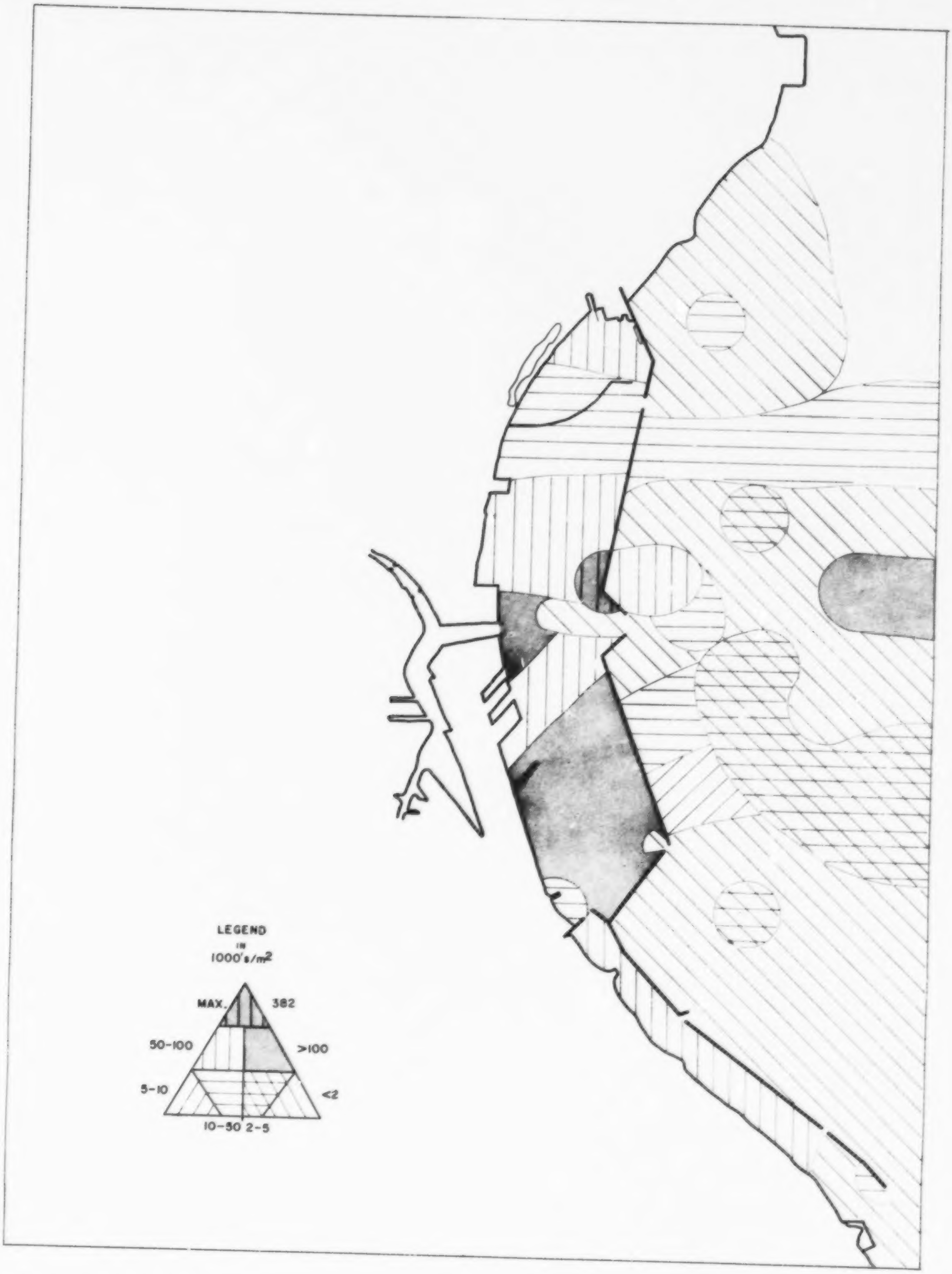
LEGEND
IN
1000's/m2
MAX.
382
50-100
>100
5-10
<2
10-50
2-5

FIG. 6. Distribution of Oligochaeta in Milwaukee Harbor.

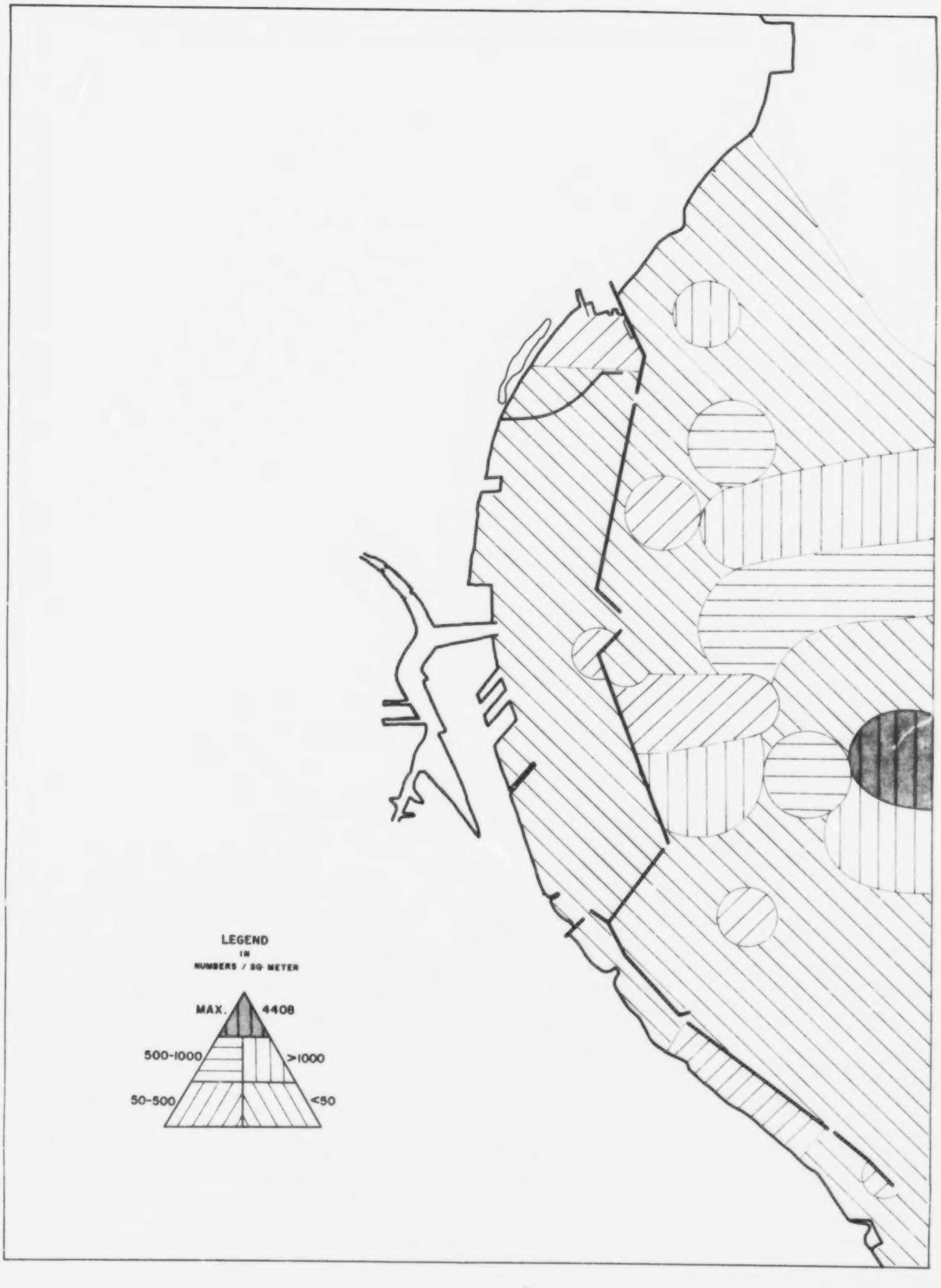
LEGEND
IN
NUMBERS / SQ METER
MAX. 4408
500-1000
>1000
50-500
<50

FIG. 7. Distribution of Amphipoda in Milwaukee Harbor.

Over most of the embayment outside the breakwaters the most common amphipod abundance was less than $50/m^2$. About a mile south and east of the main harbor entrance there was a reasonably normal population density of 4,408 amphipods per $m^2$. Throughout the rest of the embayment subnormal populations were the rule.

Localized areas of higher population of amphipods lay northeast of each harbor entrance, as though enriched water extended out in that direction.

## SPHAERIIDS

Except for the most polluted part of the harbor off Jones Island and at the mouth of the Milwaukee River, the region inside the breakwaters had a more consistently high population of sphaeriids (fingernail clams) than did the embayment outside the breakwaters (Fig. 8). The maximum number of sphaeriids was in the north-central part of the harbor where $7,224/m^2$ were found.

Over most of the embayment outside the harbor less than 50 fingernail clams/$m^2$ was the rule. Northeast from North Entrance, northeast from the main harbor entrance, and northeast from South Entrance there were concentrations of the clams in higher numbers. Some of these were very localized, but off the main entrance the area was large.

A large area of less than 50 clams/$m^2$, which extended inward from the southeast to the main harbor entrance and became confluent with the most polluted central part of the harbor, is considered an accidental agreement in numbers, the normal alongshore number happening to agree with the number surviving in the heavy pollution of the mid-harbor.

## TENDIPEDIDAE

The tendipedids (chironomids) (midge larvae) were in normal Lake Michigan concentrations in both the major part of the harbor and in the embayment outside the harbor. Only in the extreme north end of the harbor and in the south end off Bay View Park did the numbers of tendipedids exceed the normal range of 0 to about $500/m^2$. The maximum number observed was $1,376/m^2$ in the extreme north end of the harbor; $500\text{-}1000/m^2$ were present off Bay View Park.

## LEECHES, SNAILS, AND OTHER COMPONENTS

Leeches, snails, and other minor components of the benthos showed little variation in numbers except in the northern and southern ends of the harbor and off South Shore Park. The maximum population of these forms was found at one station just inside the harbor on the south side of the main entrance; here 4,128 individuals/$m^2$ were taken. Densities of $500\text{-}3000/m^2$ were present in the

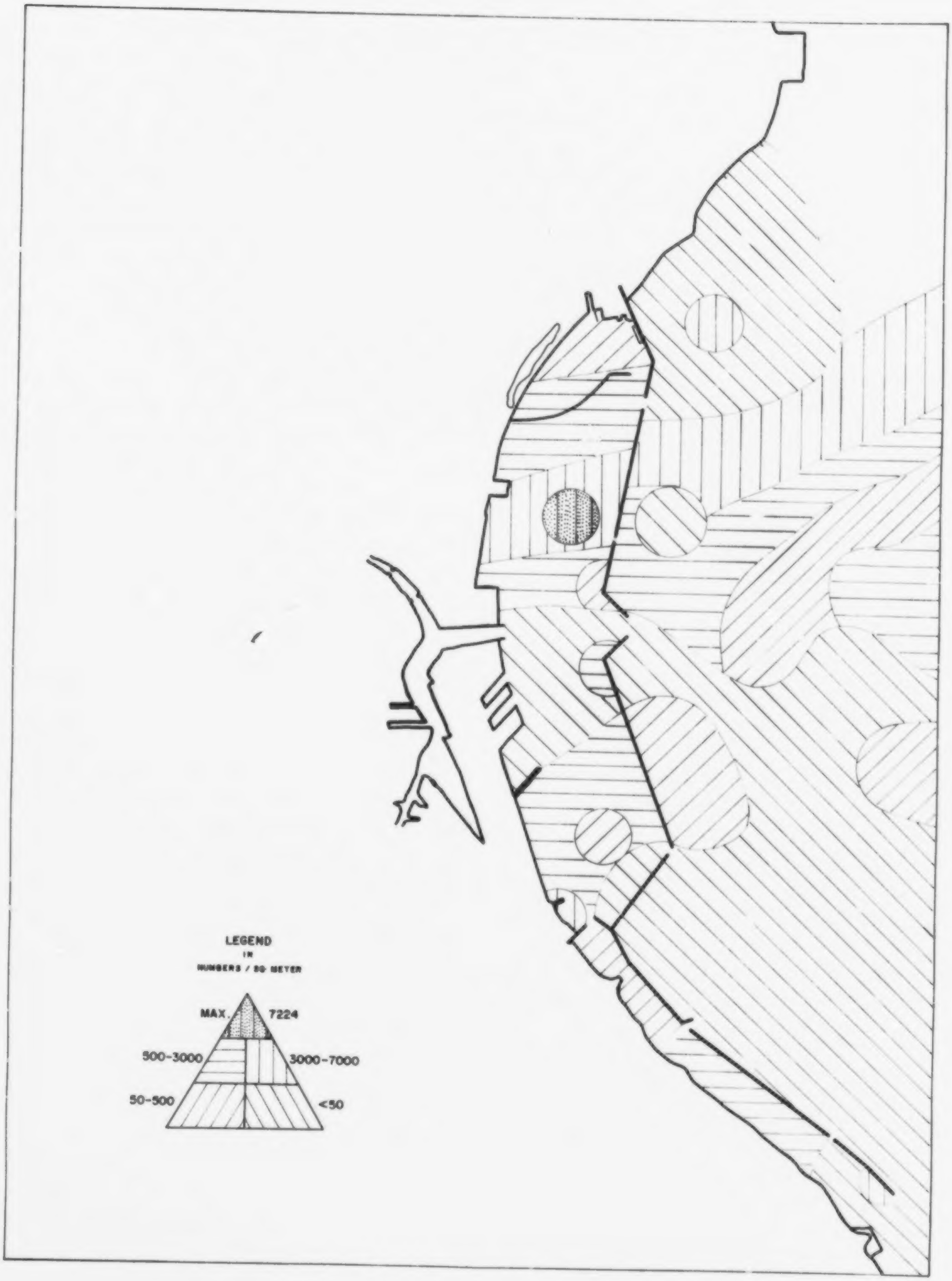
LEGEND
IN
NUMBERS / SQ METER
MAX. 7224
500-3000
3000-7000
50-500
<50

FIG. 8. Distribution of Sphaeriidae in Milwaukee Harbor.

north and south ends of the harbor. In the embayment the maximum density of these minor components were 50-500/$m^2$ at two stations near the public bathing beach just outside the north end of the harbor.

## SESTON (PARTICULATE ORGANIC MATTER)

Seston from 300 ml of water were filtered out on 0.8μ weighed Millipore filters, dried, weighed, ashed, and expressed as ashfree weight of seston. Seston filtrations, in addition to No. 5 and No. 20 net hauls, are all indicated by the "plankton" designation in the legend of Fig. 1.

Ashfree seston within the harbor averaged 1.28 mg/l; outside the breakwaters the average in the embayment was 0.79 mg/l. The latter value is well within the range of seston values from 493 samples (averages of triplicates) from the open lake where the average for 269 samples from the south end of the lake was 0.92 mg/l and the average for 224 samples from the north central portion of the lake was 0.78 mg/l.

The quick drop to open-lake values in the mile or so outside the breakwaters, again, indicates substantial mixing going on in the embayment.

## NO. 5 NET ZOOPLANKTON

The materials collected by the No. 5 plankton net averaged 1.1 mg ashfree dry weight per meter of tow at stations in the embayment. The average total ashfree material per haul was 7.4 mg. The range was from 1.6 mg total and 0.2 mg/m at station MIL-35 to 17.5 mg total and 1.5 mg/m at station MIL-1. Qualitative analysis of the material captured by the No. 5 net reveal that on the average 36% of it was zooplankton, 12% was detritus and the remainder was phytoplankton.

At stations within the harbor the averages were 6.3 mg total material per haul and 1.5 mg/m. The ranges were from 2.2 mg total and 0.7 mg/m at station MH-6 to 13.5 mg and 2.7 mg/m at station MH-21 at the Jones Island outfall. Qualitative analysis of the harbor collections showed 31% to be zooplankton, 58% to be detritus and the remainder to be phytoplankton.

## THE CLEAN-WATERNESS INDEX: AMPHIPODS/OLIGOCHAETES

Use is made of the facts that the amphipod, Pontoporeia affinis, is a lover of clean waters, and that the aquatic earthworms (tubificids) (sludgeworms) are tolerant of pollution. The value of the ratio: amphipod numbers over oligochaete numbers is taken as a measure of the integrated effects of pollution in modifying the region. Pontoporeia are in part planktonic (able to swim weakly) and are apt to be carried by current into areas where they would not live, but where they may be captured while transients; this makes the ratio probably somewhat less conservative than would be a ratio of two entirely benthic organisms. The de facto ratio of these two types of organisms as taken is considered the soundest available measure of long-term effects of man. Figure 9 presents the distribution of the ratio: amphipods over oligochaetes.

We regard the zero isoline of the ratio as significant in that it delineates the area from which Pontoporeia was excluded. This area extended from passage through the breakwater off South Shore Park. The zero isopleth protrudes from the main entrance of the harbor into the embayment in an eastward and northward direction.

The 1.0 isopleth of the ratio lies relatively close to the south end of the breakwater, is pushed lakeward off the main entrance, and swings lakeward again off North Entrance. To less extent the 0.1 and 0.01 isopleths also protrude lakeward off North Entrance.

The configurations of the isopleths again suggest a south to north long-term trend of the current through the embayment.

## DISCUSSION AND CONCLUSIONS

As was indicated earlier, our aims in this survey were threefold: (1) to investigate the possiblity that Milwaukee Harbor functions as a sewage lagoon, (2) to determine in a definitely polluted situation the levels attained by parameters being used in our studies of the eutrophication of the open lake, and (3) to determine if possible certain aspects of the physical behaviors of the harbor and embayment waters.

Studies of eutrophication in the open lake present various levels of biological parameters from which it is necessary to make judgments as to the level of eutrophication involved. The polluted waters of Milwaukee Harbor were used to establish definitely polluted base-line levels of some of our "standard" biological measurements.

Our main interest, however, was in the two physical-behavior aspects of the region: (1) is the harbor being forced to act as a sewage lagoon, and (2) why is it that, with water intakes on both sides of the harbor, Milwaukee's raw water is reputed to be of high quality?

The almost exact duplication of the distribution of total benthos (Fig. 5) by the oligochaete distribution (Fig. 6) confirms previous knowledge that oligochaetes are the overwhelmingly predominant benthic organisms of polluted waters. The results shown in Fig. 8 indicate that increased density of sphaeriids also accompanies pollution. For our specific needs in relation to open-lake studies, the north central portion of the harbor in Figs. 6, 8, and 9 has provided the base line sought, i.e., polluted waters may be suspected when oligochaetes

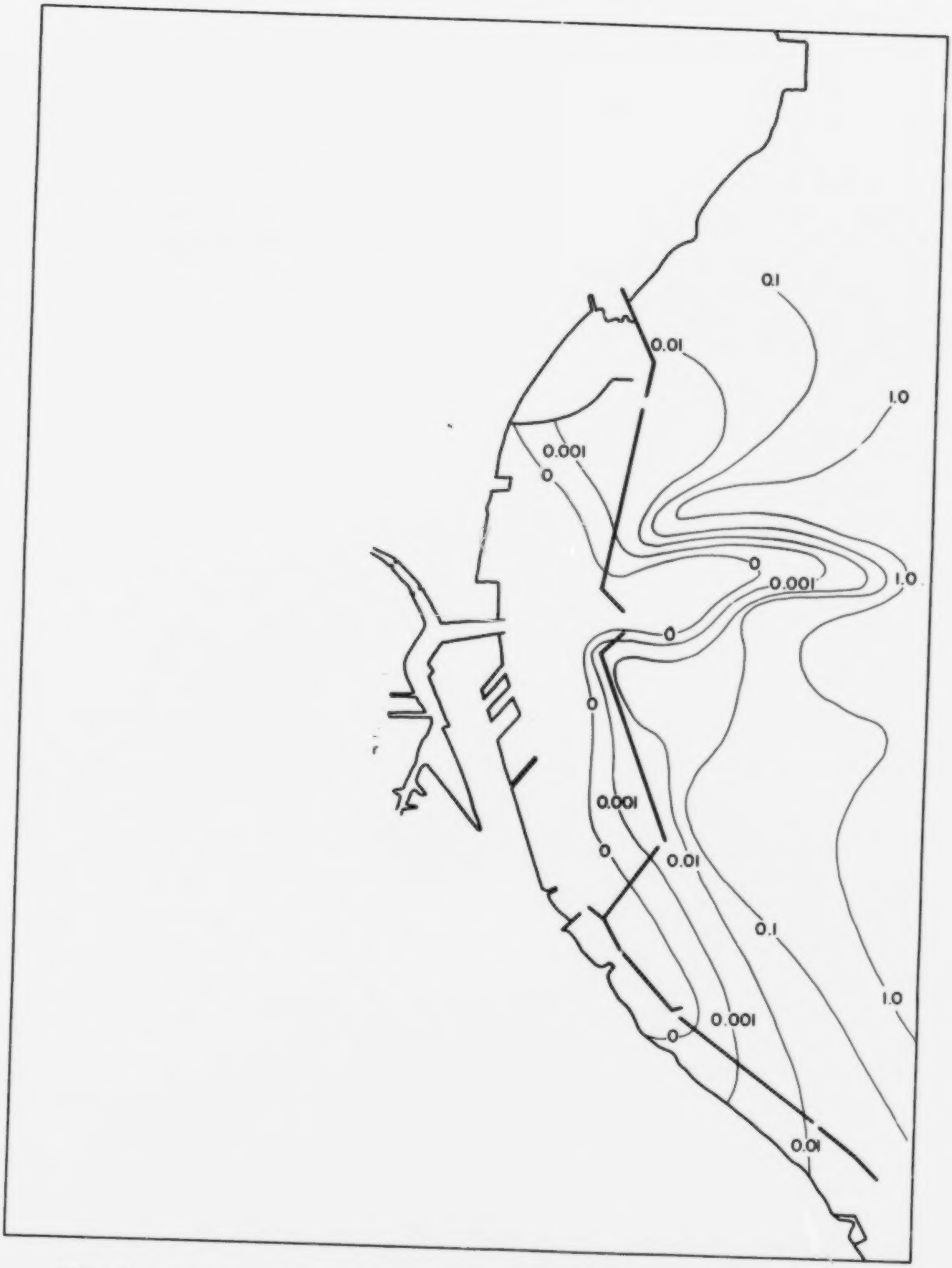
0.1
0.01
1.0
0.001
0
0
0.001
1.0
0
0
0.001
0
0.01
0.1
1.0
0.001
0
0.01

FIG. 9. Ratio, numbers of amphipods to numbers of oligochaetes.

exceed 50,000/m$^2$ and are accompanied by sphaeriids in excess of 50/m$^2$ and when these two are accompanied by zero amphipods. It further appears that an amphipod/oligochaete ratio smaller than 0.01 may be taken to indicate marginal pollution, while a ratio of 0.001 or less indicates definite pollution. It must be remembered that wave action along open beaches will exclude amphipods and produce spurious zero amphipod/oligochaete ratios.

From the present study we have not found the populations of tendipedids nor of the minor components of the benthos to have useful base-line characteristics in identifying polluted water.

The distributions of water-borne parameters such as solutes, turbidity or transparency, conductivity, and water color are of value in deducing local and short-term behavior of the water when wind at the time of sampling is recorded and kept in mind during data analysis. The distributions of transparency and sulphide in Figs. 2 and 3 are significant in that they were obtained under winds that opposed the exhibited northward and eastward movement of harbor water into the embayment.

The behaviors of these two parameters, plus tendencies for there to be higher concentrations of benthic organisms to the north and east of the openings through the breakwaters, plus an extensive area of silt-containing sediment outside the harbor in Fig. 4, are all interpreted as indicating that Milwaukee Harbor is serving in some real degree the function of a sewage lagoon (a very leaky sewage lagoon) in which settlement and mineralization take place.

The northward and eastward protrusions of low transparency and high sulphide (Figs. 2 and 3) are taken to indicate a south-to-north water current through the embayment on the three days when the embayment stations were sampled. Sediment types and the distributions of benthic organisms may be expected to reflect, if anything, the long-term mean movements of water current. Tendencies toward higher concentration of benthic organisms to the north and east of the harbor openings have been pointed out. The northeastward extension of gravel bottom from the main harbor entrance in Fig. 4 is taken to indicate long-term tendency of harbor effluent to move northeastward from the main entrance. Low numbers of benthic organisms in the southern part of the embayment (Figs. 5 through 8) are taken to mean that the detritus- and bacteria-rich harbor waters do not have a long-term mean movement to the southeast; alternatively, the higher numbers northeastward from the harbor openings are in about the proper places if these organisms derive nourishment from the detritus and bacteria of harbor waters moving out to north and east. The 0.1 and 1.0 isopleths of the amphipod/oligochaete ratio lie close to shore in the south end of the embayment but are bulged away from shore in the north end. The protrusion of the 0 isopleth of the ratio out through the main harbor entrance has both eastward and northward components.

While these data are indirect, the preponderance of their indications are consistent with a water current from south to north as the long-term mean direction. This conclusion is also compatible with the Department of Interior

FWPCA (1966) current measurements near Milwaukee during 33 months beginning in 1962 and ending in 1964. Figures 5-1 and 5-2 of that report show primary northward current through the embayment during the seven months September through March and weaker primary southward current during the five months April through August. Bellaire (1964) found northward currents along Milwaukee during four days of October 1963.

It appears that the mechanisms that make it possible for Milwaukee to draw good-quality raw water from intakes on both sides of the polluted harbor are the dominance of northward current and the lakeward protrusion of land north of the harbor which causes the current to impinge against shore along the northern headland. The northern, or Linnwood Ave., intake reaches 6565 ft into the lake and to 60 ft of depth off the northern headland, and most of the harbor effluent probably does not get that far off shore much of the time. The southern, or Texas Ave., intake extends 7600 ft into the lake to 50 ft of depth in a northeast direction from the beach at Bay View Park. Station MIL-42 lies a few hundred feet east of the intake crib. A dominant northward current would protect this intake the majority of the time. Both intakes probably receive diluted harbor effluent short periods when wind conditions are right.

## REFERENCES

BELLAIRE, F. R. 1964. A comparison of methods of current determinations. Proc. 7th Conf. on Great Lakes Research; Great Lakes Res. Div. Pub. No. 7, p. 171-178, Univ. Michigan, Ann Arbor.

U.S. DEPARTMENT OF THE INTERIOR. 1966. Comprehensive water pollution control program for the Lake Michigan Basin, Milwaukee Area, Wis. Federal Water Pollution Control Administration, Great Lakes-Illinois River Basins Project. Region V, Chicago, Illinois. 66 p., 10 figs., numerous tables.

# THE INTERNAL DISTRIBUTION OF ANALYSIS VALUES AS AN INDICATOR OF EUTROPHICATION

John C. Ayers

## INTRODUCTION

The awareness that natural waters undergo changes as the result of fertilization by added quantities of solutes, whether these additions come from natural causes, from man's polluting activities, or from man's deliberate addition of fertilizers, has led in recent years to efforts to find reliable indicators of the trophic levels of natural waters. In part these have been attempts to find reasonable means of defining relative levels of eutrophication in lake-to-lake or stream-to-stream comparisons. In part they have been efforts to define present status of eutrophication in individual lakes or streams known to be, or suspected of being, in modification by the fertilization incident to man's polluting activities. Most of these searches have contributed to the accumulation of criteria by which definitely eutrophied waters can be distinguished from unmodified (oligotrophic) waters, but to our knowledge no sensitive criteria have been found by which small degrees of trophic difference can be distinguished.

The southern two-thirds of Lake Michigan is an aquatic environment of about 12,000 square miles area wherein the extreme southern end (south of sampling line A in Fig. 1) is modified by pollution (U.S. Public Health Service 1965; Risley and Fuller 1965). The central and north central portions of the lake undoubtedly receive some indirect modification by current-carried materials from the south end, but the usual criteria for trophic level yield only glimpses of possible differences in eutrophication between station lines A and B in the southern end and lines D and E in the north central part.

Such an environment seemed a suitable place in which to seek more sensitive indicators of eutrophication. Biological, chemical and physical data in significantly large numbers, from all depths, and from spring, summer and fall were available with which to work.

Biological indications of difference in trophic level were sought by Robertson and Powers (1965), Powers and Robertson (1965) and by Scarce (1965). These studies demonstrated inshore-offshore differences within every sampling line but did not show any clear south-north difference in eutrophication.

Chemical indications of trophic level were slightly better. Risley and Fuller (1965) definitely identified and eutrophied extreme southern end of the lake. They also indicated somewhat higher levels of some solutes over the southern third of the lake but did not claim chemical indication of small dif-

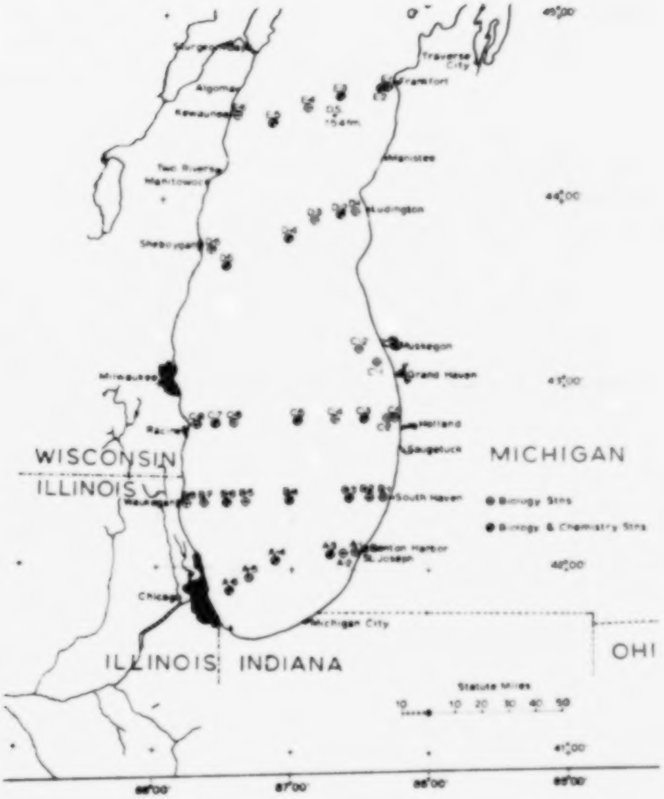
Sturgeon Bay
Algoma
Kewaunee
Two Rivers
Manitowoc
Sheboygan
Milwaukee
Racine
Waukegan
Chicago
Traverse City
Frankfort
Manistee
Ludington
Muskegon
Grand Haven
Holland
Saugatuck
South Haven
Benton Harbor
St. Joseph
Michigan City
D5
154m
WISCONSIN
ILLINOIS
MICHIGAN
ILLINOIS
INDIANA
OHI
Biology Stns
Biology & Chemistry Stns
Statute Miles
10
10
20
30
40
50
45°00'
44°00'
43°00'
42°00'
41°00'
88°00'
87°00'
86°00'
85°00'

FIG. 1. The A- through E-lines of sampling stations in Lake Michigan.

ferences of trophic level from south to north outside the damaged southern end. They even commented on the south to north uniformity. Our own chemical data, studied in the usual ways, could distinguish the modified area in the extreme south end of the lake but could not show real distinction between the A and B lines of sampling stations and the D and E lines.

Physical parameters apt to be indirectly influenced by changed biological activity under the stimulus of eutrophying solutes were examined. Of these, conductivity (specific conductance) and total dissolved solids (filterable residue) were available in large numbers from all stations, all depths, and all three seasons. By the usual study methods these parameters showed some modification of the extreme south end of the lake but did not show demonstrable difference between the south and north central parts of the lake.

## AN HYPOTHESIS

Basic considerations indicate that an unmodified lake should be low in solutes, for only natural leaching from its watershed is operative. Unless the rock of the watershed were exceptional, such a pristine lake would be oligotrophic.

With the appearance of man's wastes an originally unmodified lake could be expected to be receiving its natural load of leachates, plus increasing amounts of wastes as the human population increased. Man's domestic wastes are produced in quantities roughly proportional to the population size. Man's industrial wastes are in part population-dependent in quantity, but also involve an additional dump-when-used-up or dump-when-full sporadic production that tends to be of more concentrated materials. An eutrophying lake receiving man's domestic and industrial wastes, therefore, should be receiving (1) its natural leachates, (2) a population-dependent uniformly supplied load of solutes reaching higher values, and (3) random slugs of solutes of various levels reaching into still-higher concentrations.

If the above reasoning holds, a large series of solute analyses on water samples from an unmodified lake should yield a high percentage of low solute values, with only a few larger values as chance natural higher concentrations were sampled.

A large series of solute analyses on water samples from an eutrophying lake might be expected to show a different distribution of values. The distribution of solute values from such a lake should reflect the low levels of natural leachates, plus the higher values from domestic wastes, plus the high and still-higher values from slugs of industrial wastes.

The two above concepts are shown graphically in Fig. 2. In both parts of this figure the circled points represent the percentage frequency of occurrence of analysis values after they have been grouped into classes of small range of solute content, and with the frequency of each class of values plotted on the midpoint value of its solute range.

The use of percentage of values falling into range classes is the basic step in developing the frequency curve, a standard statistical device used in styding natural populations. The curves drawn through the circled points in Fig. 2 are frequency curves.

The frequency curve of a population of solute analyses from an unmodified lake might be expected to be concentrated toward the low values and to have a tendency to reach its peak frequency in the low values. A population of solute analyses from an eutrophying lake might be expected to present a frequency curve more similar in shape to those presented by normal natural populations, i.e., relatively bell-shaped, with the heaviest concentration of values nearer the middle of the range and with a wider range of values along the base of the curve. Because of the various higher values from the added wastes, the frequency curve of samples from an eutrophying lake might also be expected to have a less pronounced peak than would a curve from samples from an unmodified lake.

The hypothesis has led to the possibility that the frequency curve, and the statistical relationships associated with it, may reflect the state of the local eutrophication process. It appears that the frequency curve and its associated relationships may be meaningful and sensitive tools with which to investigate degree of eutrophication.

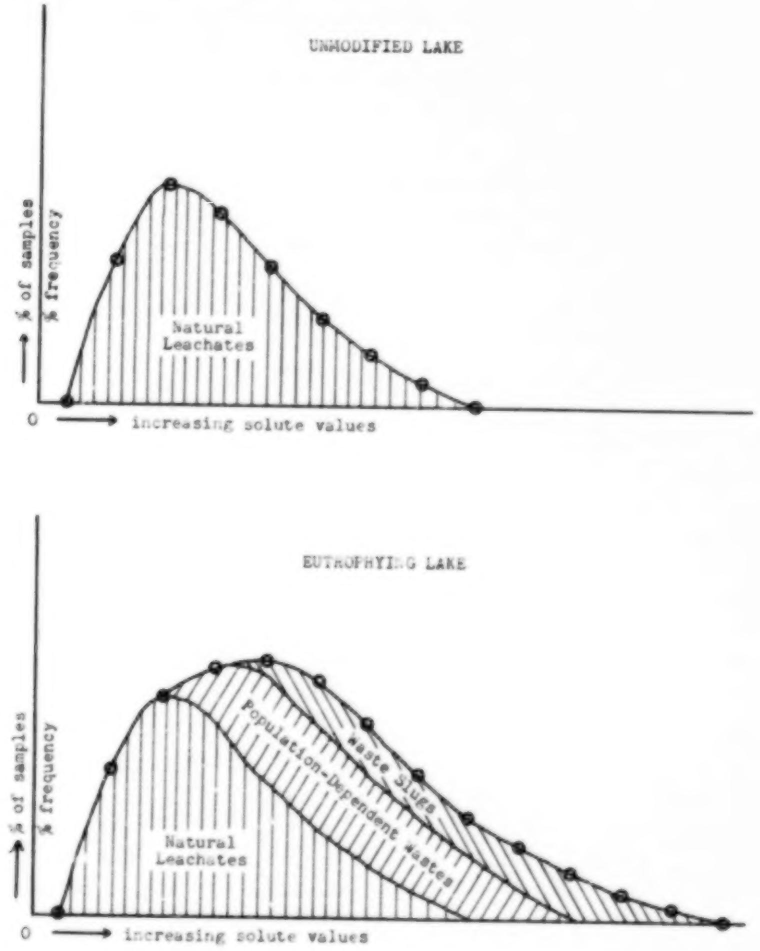

FIG. 2. Hypothesized distributions of solute analysis-values.

## METHODS AND MATERIALS

Following the above hypothesis, our available data were analyzed by the frequency curve method, i.e., the data from the five lines of stations (A through E) were made into frequency curves. The data were first grouped into small-interval classes of values on a tally sheet. From the tally sheet, by inspection, was chosen the smallest class interval of values that would permit the numbers of grouped data per class to rise from zero by progressively larger numbers upward to a peak, then by progressively smaller numbers downward to zero again. When analysis values of zero were present, a still lower class-interval of the same size but in the negative values was inserted to provide the initial zero frequency of occurrence. The numbers of data per class in the final class groupings were converted to percentage frequency of occurrence and from these percentage frequencies the frequency curves were constructed. Also from these percentage frequencies, by cumulative summation, were constructed graphs of cumulative frequency from which were read the 90th, 50th, and 10th percentile analysis value levels and the 1st and 3rd quartile (25th and 75th percentile) value levels. The percentile and quartile value levels were used in computations of the skewness and kurtosis of the frequency curves.

In working with the tally sheets, frequency curves and cumulative curves it soon became evident that the internal distributions of analysis values from lines A and B were different in varying degrees from those of values from lines D and E. Values from stations in line C sometimes were internally distributed like those of lines A and B, sometimes were like those of lines D and E, and sometimes were intermediate between them. This was taken to indicate that line C was in a mixing region that received waters from both north and south, consequently data from line C were not used in the present studies. Since the distributional behaviors of data from lines A and B were similar, and since both lines were in the southern part of the lake, their data were combined to obtain the advantage of greater numbers. For the same reasons the data from lines D and E in the north central part of the lake were combined. The two sets of combined data were then compared for differences of internal distributional behavior that might be used as indicators of difference in eutrophic levels.

The data available were of the following sorts:

Inorganic Solutes

- Ortho-phosphorus
- Sulphates

Inorganic-Organic Combinations

- Total phosphorus
- Kjeldahl nitrogen
- Ash of dissolved solids
- Ashfree dissolved solids (ignition loss of total dissolved solids)

Physical Parameters Reflecting Inorganic-Organic Combinations

- Total dissolved solids (filterable residue)
- Conductivity (specific conductance)

Bio-Organic Parameters

- Ashfree seston (ashfree suspended particulate matter)
- Seston ash

The numbers of analysis values available are given in Table 1. Though the data are not exactly equivalent they are considered to have a good degree of comparability. The ranges of depth in the four lines overlap largely, though not completely. Numbers of stations generally were 14 in lines A, B and 12 in lines D, E. Samples were nearly always within the same two weeks, and usually within the same week. Each line was sampled approximately the same number of times in each of the three seasons. Six of the nine samples for chemistry, total dissolved solids, seston, and dissolved organic matter were at identical depths; in the cases of total dissolved solids, seston, seston ash, dissolved organic matter and ash of dissolved organic matter, each datum was the average of triplicate samples. Perhaps the most telling evidence of equivalency between the data is that the usual comparisons to environmental factors gave the same relationships in each of the four lines of stations.

TABLE 1. Numbers of data available and times of sampling.

| | Lines A, B | | | Lines D, E | | |
|---|---|---|---|---|---|---|
| | Sampling | Dates | Sample No. | Sampling | Dates | Sample No. |
| Ortho-phosphorus | Apr-Aug | 1964 | 91 | June-Aug | 1964 | 73 |
| Sulphates | Apr-Oct | 1964 | 149 | May-Oct | 1964 | 140 |
| Total phosphorus | Apr-Nov | 1964 | 155 | May-Nov | 1964 | 174 |
| Kjeldahl nitrogen | Apr-Nov | 1964 | 159 | May-Nov | 1964 | 171 |
| Ashfree dissolved solids | Apr-Nov | 1965 | | Apr-Nov | 1965 | |
| | Mar-June | 1966 | 165* | Mar-June | 1966 | 144* |
| Ash of dissolved organic matter | Apr-Nov | 1965 | | Apr-Nov | 1965 | |
| | Mar-June | 1966 | 165* | Mar-June | 1966 | 144* |
| Ash of dissolved solids | Apr-Nov | 1965 | | Apr-Nov | 1965 | |
| | Mar-June | 1966 | 165* | Mar-June | 1966 | 144* |
| Conductivity | Apr-Nov | 1964 | 168 | May-Nov | 1964 | 172 |
| Ashfree seston | Apr-Nov | 1964 | | May-Nov | 1964 | |
| | Apr-Nov | 1965 | | Apr-Nov | 1965 | |
| | Apr-June | 1966 | 269* | Apr-June | 1966 | 224* |
| Seston ash | Apr-Nov | 1964 | | May-Nov | 1964 | |
| | Apr-Nov | 1965 | | Apr-Nov | 1965 | |
| | Apr-June | 1966 | 269* | Apr-June | 1966 | 224* |

*Average of triplicate samples.

## RESULTS

Differences in skewness (displacement of the peak of the frequency curve away from the center of the range of values) and differences in kurtosis peakedness; narrowness of the peak of the frequency curve relative to the range of values) were present between lines A, B and lines D, E. In many cases these differences were visually evident in the tally sheets; in such cases graphing the frequency curves, the cumulative curves, and computing skewness and kurtosis was merely confirming the obvious. In some cases visual differences were not evident, and computation was necessary to determine subtle differences in skewness and kurtosis.

The relative skewness and kurtosis of data from lines A, B and D, E are shown in Table 2.

TABLE 2. Relative skewness and kurtosis.

| | Lines A,B | Lines D,E |
|---|---|---|
| Ortho-phosphorus | | more skewed<br>more peaked |
| Sulphate | | more skewed<br>more peaked |
| Total phosphorus | | more skewed<br>more peaked |
| Kjeldahl nitrogen | more skewed<br>more peaked | |
| Ashfree dissolved solids | more skewed<br>more peaked | |
| Ash of dissolved solids | more peaked | more skewed |
| Total dissolved solids | more skewed<br>more peaked | |
| Conductivity | | more skewed<br>more peaked |
| Ashfree seston | more peaked | more skewed |
| Seston ash | | more skewed<br>more peaked |

The total results are presented in Table 3. In this table the mean is the arithmetic mean, the median is the 50th percentile, the mode is the central digit (class mark) of the ranking-class in which the greatest number of analysis values occurred, and for comparison the midpoint of the range of values is included. Skewness and kurtosis values shown in the table are computed from:

$$\text{Skewness} = P_{90} + P_{10} - 2P_{50}/P_{90}-P_{10} \qquad (1)$$

$$\text{Kurtosis} = Q_3 - Q_1/2(P_{90}-P_{10}) \qquad (2)$$

wherein the P and Q factors are the percentile and quartile analysis value levels, read where the cumulative percentage curve crosses 10, 25, 50, 75, and 90%.

Table 2 shows that the frequency curve analysis brings out three types of different internal-distribution behaviors among the data from otherwise almost-undistinguishable lines A, B and D, E.

In one type of distributional behavior, curves for lines D, E are more skewed and more peaked than are curves for A, B. In a second behavior, greater skewness and greater peakedness are separated between the two pairs of lines. In the third, the curves for lines A, B are more skewed and more peaked than are those of lines D, E.

Table 3 shows that there are various degrees in the difference of skewness and kurtosis that are brought out by the frequency-analysis technique. Perhaps the most extreme is the difference in distribution in ortho-phosphorus. With this solute there is no need to go beyond the tally sheet, which is reproduced as Fig. 3. The skewness of the values from lines D, E into the low values is visually evident, as is also the presence of a clear peak in the .11-.20 ppb class of lines D, E. Less sharp skewness away from midrange and a somewhat smeared peak are shown by lines A, B. Ortho-phosphorus is an example of the first type of distributional behavior listed in the paragraph above.

The separated type of internal distribution is exemplified by the ash of dissolved solids. This tally sheet is given as Fig. 4; with some experience it is visually useful. The displacement of the peak of value frequencies of lines D, E toward the lower values is evident, but the peakedness of this curve is spoiled by its smaller total range and a "shoulder" involving the classes between 90.1 and 105.0 mg/l. The data from lines A, B are more peaked by virtue of their lack of "shoulders" and the greater overall range, since kurtosis expresses relative narrowness of the frequency peak in comparison to width of base (range).

TABLE 3. Results of frequency-curve analysis, southern lines A, B vs. north central lines D, E.

| | Skewness* | Kurtosis** | Mean | Median | Mode | Range Midpoint | $P_{90}$ | $Q_3$ | $P_{50}$ | $Q_1$ | $P_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ortho-P, ppb | | | | | | | | | | | |
| Lines A,B | 0.38 | 0.13 | 0.78 | 0.34 | 1.05 | 1.21 | 0.74 | 0.40 | 0.34 | 0.32 | 0.16 |
| Lines D,E | 0.74 | -0.27 | 0.38 | 0.20 | 0.35 | 0.85 | 0.408 | -0.05 | -0.20 | -0.24 | -0.29 |
| Sulphate, ppm | | | | | | | | | | | |
| Lines A,B | 0.22 | 0.24 | 16.6 | 14.8 | 17.5 | 16.75 | 17.8 | 16.3 | 14.8 | 14.0 | 12.9 |
| Lines D,E | 0.38 | 0.20 | 16.3 | 14.3 | 14.5 | 18.00 | 17.6 | 15.5 | 14.3 | 13.6 | 12.8 |
| Total P, ppb | | | | | | | | | | | |
| Lines A,B | 0.58 | 0.23 | 4.9 | 0.0 | 3.0 | 12.5 | 9.5 | 4.0 | 0.0 | 4.0 | -2.5 |
| Lines D,E | 0.73 | 0.21 | 5.3 | -1.2 | 3.0 | 13.1 | 9.5 | 2.8 | -1.2 | -2.8 | -2.9 |
| Kjeldahl N., ppm | | | | | | | | | | | |
| Lines A,B | 0.38 | 0.19 | 0.109 | 0.044 | 0.04 | 0.240 | 0.160 | 0.08 | 0.044 | 0.016 | -0.008 |
| Lines D,E | 0.19 | 0.26 | 0.083 | 0.033 | 0.04 | 0.135 | 0.113 | 0.07 | 0.033 | 0.0 | -0.022 |
| Ashfree Diss. Solids, mg/l | | | | | | | | | | | |
| Lines A,B | 0.25 | 0.22 | 77.5 | 67.0 | 67.5 | 88.8 | 94.0 | 79.5 | 67.0 | 60.2 | 50.7 |
| Lines D,E | 0.14 | 0.25 | 78.8 | 69.5 | 67.5 | 86.5 | 90.9 | 80.3 | 69.5 | 61.8 | 53.2 |
| Ash of Diss. Solids, mg/l | | | | | | | | | | | |
| Lines A,B | 0.05 | 0.22 | 88.5 | 83.5 | 85.0 | 97.0 | 96.4 | 86.4 | 83.5 | 76.0 | 71.8 |
| Lines D,E | 0.31 | 0.31 | 89.6 | 82.1 | 85.0 | 94.6 | 98.0 | 91.8 | 82.1 | 77.0 | 73.8 |
| Total Diss. Sol., mg/l | | | | | | | | | | | |
| Lines A,B | 0.25 | 0.236 | 166.0 | 153.0 | 165.0 | 181.6 | 183.0 | 165.8 | 153.0 | 143.2 | 135.0 |
| Lines D,E | 0.11 | 0.243 | 168.4 | 156.0 | 165.0 | 176.0 | 180.5 | 167.2 | 156.0 | 145.8 | 136.5 |
| Conductivity, µ mhos (25°) | | | | | | | | | | | |
| Lines A,B | -0.03 | 0.28 | 244.6 | 242.7 | 246.5 | 245.0 | 249.5 | 246.2 | 242.7 | 238.2 | 235.5 |
| Lines D,E | -0.06 | 0.18 | 245.3 | 243.5 | 246.5 | 245.5 | 251.0 | 246.5 | 243.5 | 240.5 | 235.0 |
| Ashfree Sest., mg/l | | | | | | | | | | | |
| Lines A,B | 0.29 | 0.23 | 0.92 | 0.76 | 0.70 | 1.12 | 1.34 | 0.99 | 0.76 | 0.579 | 0.44 |
| Lines D,E | 0.36 | 0.27 | 0.78 | 0.605 | 0.70 | 0.88 | 1.035 | 0.835 | 0.605 | 0.499 | 0.401 |
| Seston Ash, mg/l | | | | | | | | | | | |
| Lines A,B | 0.13 | 0.27 | 0.96 | 0.71 | 0.60 | 1.23 | 1.40 | 1.08 | 0.71 | 0.41 | 0.18 |
| Lines D,E | 0.15 | 0.24 | 0.69 | 0.43 | 0.60 | 1.05 | 1.00 | 0.675 | 0.43 | 0.215 | 0.01 |

*Skewness: larger value = greater skewness.

**Kurtosis: smaller value = greater peakedness.

| Classes of ppb | Lines A, B | Lines D, E |
|---|---|---|
| 0 | 𝍸𝍸 | 𝍸\|\|\| |
| .01 - .10 | | 𝍸\|\| |
| .11 - .20 | | 𝍸𝍸𝍸𝍸 |
| .21 - .30 | | 𝍸𝍸\|\|\| |
| .31 - .40 | | 𝍸\|\| |
| .41 - .50 | | \|\| |
| .51 - .60 | 𝍸\| | \|\|\|\| |
| .61 - .70 | 𝍸𝍸𝍸\|\|\| | \|\|\|\| |
| .71 - .80 | 𝍸𝍸𝍸𝍸 | \| |
| .81 - .90 | 𝍸𝍸 | \| |
| .91 - 1.00 | 𝍸𝍸\|\|\| | \|\| |
| 1.01 - 1.10 | 𝍸\| | \| |
| 1.11 - 1.20 | | |
| 1.21 - 1.30 | \| | |
| 1.31 - 1.40 | \|\|\| | |
| 1.41 - 1.50 | | \| |
| 1.51 - 1.60 | \| | \| |
| 1.61 - 1.70 | | \| |
| 1.71 - 1.80 | \| | |
| 1.81 - 1.90 | | |
| 1.91 - 2.00 | | |
| 2.01 - 2.10 | \| | |
| 2.11 - 2.20 | | |
| 2.21 - 2.30 | | |
| 2.31 - 2.40 | | |
| 2.41 - 2.50 | \| | |

FIG. 3. Tally sheet, ortho-phosphorus.

| Classes of mg/l | lines A, B | lines D, E |
|---|---|---|
| 60.1 - 65.0 | | |
| 65.1 - 70.0 | \|\| | \| |
| 70.1 - 75.0 | 𝍸\|\| | 𝍸 |
| 75.1 - 80.0 | 𝍸𝍸𝍸𝍸\|\|\|\| | 𝍸𝍸𝍸\|\| |
| 80.1 - 85.0 | 𝍸𝍸𝍸𝍸𝍸𝍸𝍸\| | 𝍸𝍸𝍸𝍸𝍸\|\|\| |
| 85.1 - 90.0 | 𝍸𝍸𝍸𝍸𝍸𝍸𝍸 | 𝍸𝍸𝍸𝍸𝍸𝍸𝍸\|\| |
| 90.1 - 95.0 | 𝍸𝍸𝍸𝍸𝍸\|\|\|\| | 𝍸𝍸𝍸 |
| 95.1 - 100.0 | 𝍸𝍸𝍸 | 𝍸𝍸\|\|\|\| |
| 100.1 - 105.0 | 𝍸\| | 𝍸𝍸\|\|\|\| |
| 105.1 - 110.0 | \|\|\|\| | 𝍸\| |
| 110.1 - 115.0 | \|\|\|\| | \|\|\| |
| 115.1 - 120.0 | \|\| | \|\| |
| 120.1 - 125.0 | | \| |
| 125.1 - 130.0 | \|\| | |

FIG. 4. Tally sheet, ash of total dissolved solids.

The type of value distributions wherein lines A, B are more skewed and more peaked than lines D, E is exhibited by ashfree dissolved solids. The tally sheet of this parameter is reproduced as Fig. 5. Even with experience it is not easy nor dependable to estimate skewness or kurtosis from distributions as similar as these. Table 4 shows the final class-rankings, percentage frequencies, and class marks utilized in construction of the frequency curves of ashfree dissolved solids (Fig. 6).

Figure 6 visually shows the curve for lines A, B to be displaced farther to the left away from midrange (more skewed). It also shows a flatness in the peak of the curve for lines D, E. Since both curves have the same basal range, the sharper peak of the curve for lines A, B visually denotes its greater kurtosis.

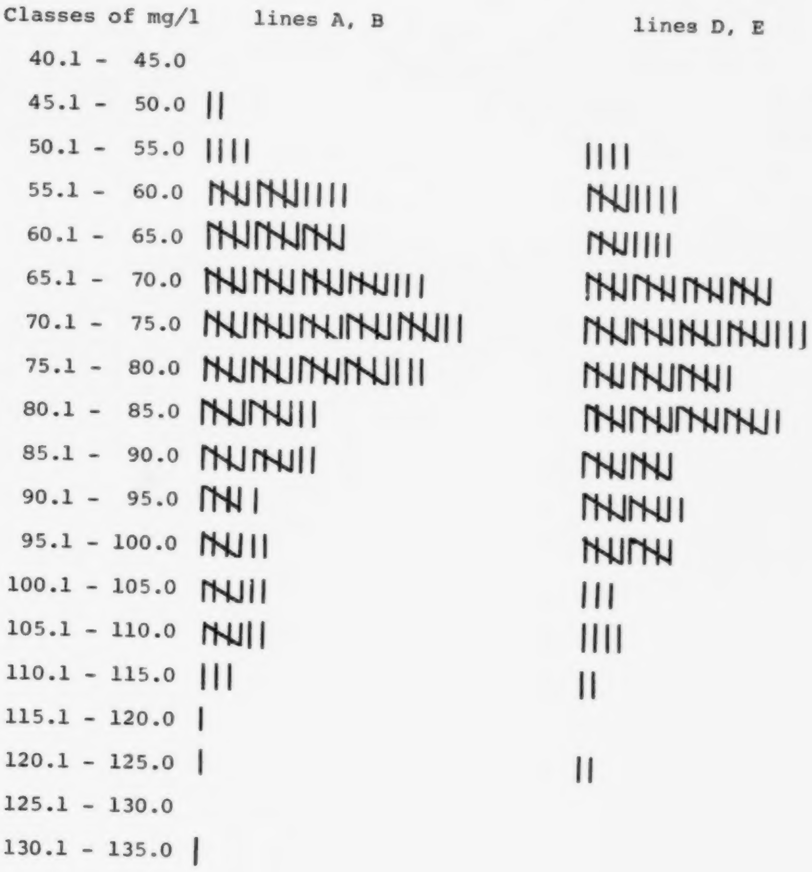
Classes of mg/l
lines A, B
lines D, E
40.1 - 45.0
45.1 - 50.0
50.1 - 55.0
55.1 - 60.0
60.1 - 65.0
65.1 - 70.0
70.1 - 75.0
75.1 - 80.0
80.1 - 85.0
85.1 - 90.0
90.1 - 95.0
95.1 - 100.0
100.1 - 105.0
105.1 - 110.0
110.1 - 115.0
115.1 - 120.0
120.1 - 125.0
125.1 - 130.0
130.1 - 135.0

FIG. 5. Tally sheet, ashfree dissolved solids.

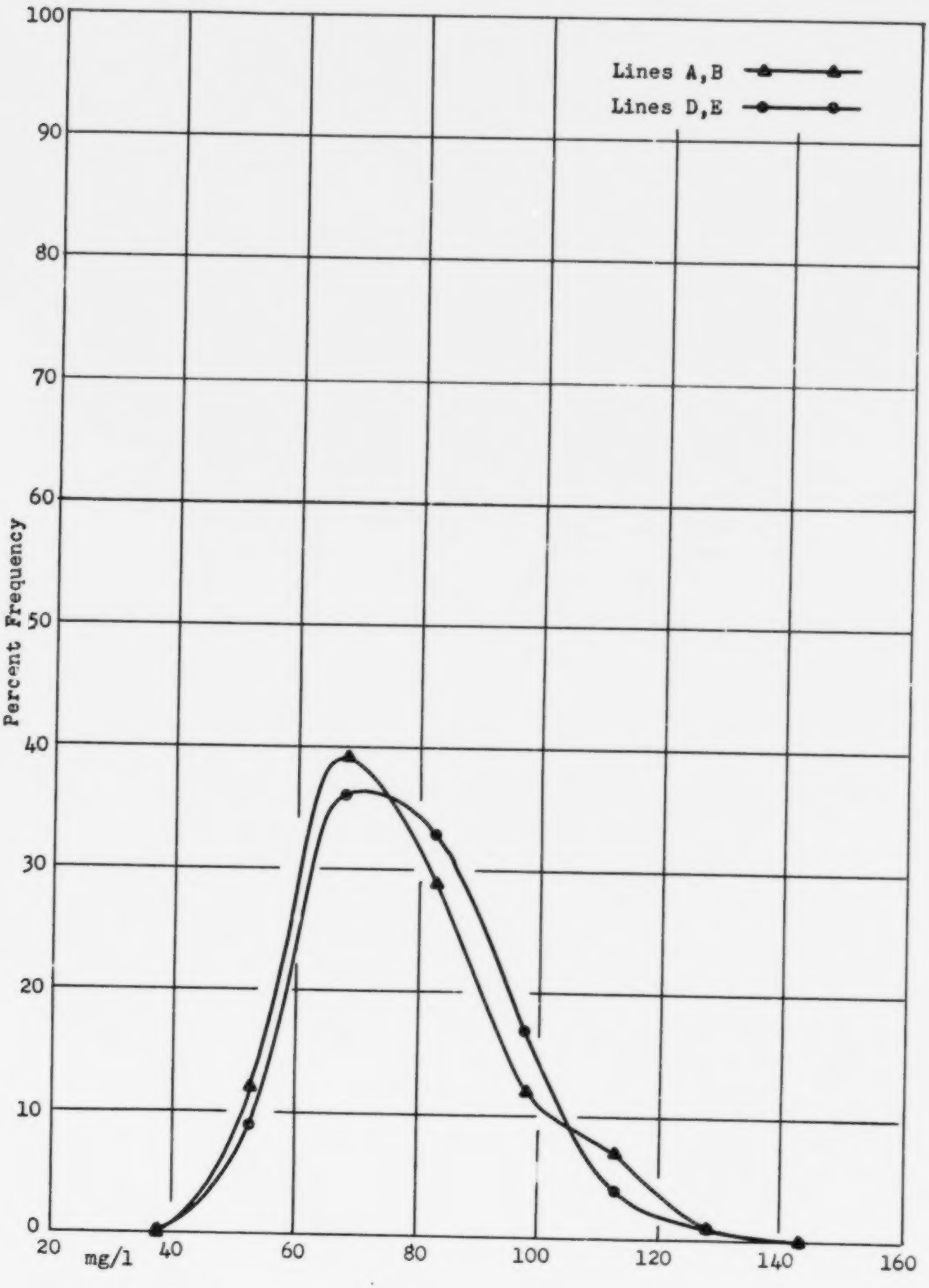

FIG. 6. Frequency curves of ashfree dissolved solids.

TABLE 4. Class-rankings, percent frequencies and class marks of ashfree dissolved solids.

| Classes of mg/l | Class Mark | Lines A, B | | | Lines D, E | | |
|---|---|---|---|---|---|---|---|
| 30.1 - 45.0 | 37.5 | 0 | = | 0% | 0 | = | 0% |
| 45.1 - 60.0 | 52.7 | 20 | = | 12% | 13 | = | 9% |
| 60.1 - 75.0 | 67.5 | 65 | = | 39% | 52 | = | 36% |
| 75.1 - 90.0 | 82.5 | 47 | = | 29% | 47 | = | 33% |
| 90.1 - 105.0 | 97.5 | 20 | = | 12% | 24 | = | 17% |
| 105.1 - 120.0 | 112.5 | 11 | = | 7% | 6 | = | 4% |
| 120.1 - 135.0 | 127.5 | 2 | = | 1% | 2 | = | 1% |
| 135.1 - 150.0 | 142.5 | 0 | = | 0% | 0 | = | 0% |
| | Sums | 165 | | 100% | 144 | | 100% |

From the percentage frequencies in Table 4, by progressive summation, were drawn the cumulative frequency curves of Fig. 7. Figure 7 shows the places where percentile and quartile levels of mg/l were read. The percentile and quartile levels of mg/l were used in Eqs. (1) and (2) to obtain the skewness and kurtosis values shown in Table 3.

Evaluations of subtle differences can be obtained only by going through the entire process. In the case of seston ash (see Table 3) no visual indication was obtained from the curves, and only the computations defined the very slight differences between the two sets of data.

The frequency-curve analysis technique has brought out distinctions between the data of lines A, B and lines D, E which it has not been possible to find previously.

## DISCUSSION

The results in Tables 1, 2, and 3 were arbitrarily arranged on the basis of general composition and in approximate order of increasing complexity of composition. Under this arrangement the results do not make much sense (see Table 2). Apparently arrangement on this compositional basis is not ecologically valid.

If the different behaviors of the data from lines A, B and D, E are ecologically real, they should fit into (or even better yet, provide) a sound scheme by which the results can be explained and understood.

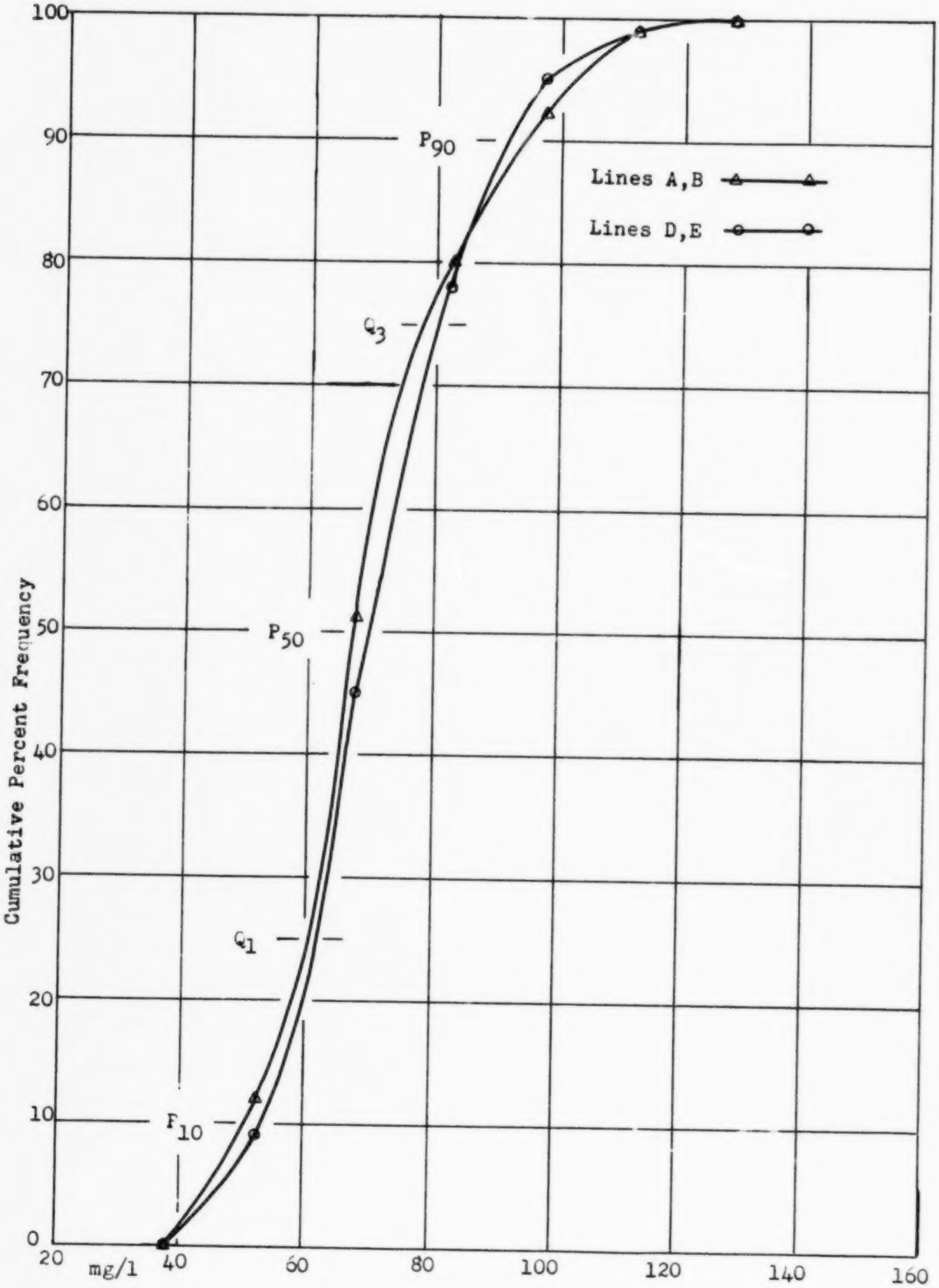

FIG. 7. Cumulative frequency curves of ashfree dissolved solids.

In the following discussion, use is made primarily of the differences and similarities in placement of greatest skewness or kurtosis. Inorganic solutes are considered the fundamental ingredients of the biological structure. More peaking and skewness in lines D, E, as shown by ortho-phosphate and sulphate, is considered distributional behavior typical of the inorganics. Greater skewness and peaking in lines A, B is considered a behavior opposite to that of the inorganic solutes.

The findings that seston ash behaved like the inorganic solutes by being more skewed and peaked in lines D, E, and that ash dissolved solids was more skewed in D, E, suggested that ash fractions resemble inorganic solutes. It is evident that ash should contain the inorganic solutes that were in the biologic process (minus some fractions driven off during the ignition process and plus oxygen picked up during ignition).

The behaviors of the data for ashfree seston and ashfree dissolved solids are conformable to present thought insofar as they represent different steps in a time relation to the basic productivity where inorganic solutes act directly as protoplasmic building-blocks. The living cells in seston are the first step after the basic productivity and, through the action of limiting factors, respond more or less directly to abundance of inorganic solutes. The newly dead detritus in seston is a second step beyond the basic productivity, and with decomposition since death, may no longer reflect the variation in inorganic solutes that directly affected the living cells. It is reasonable, then, that ashfree seston should behave less like inorganic solutes than does seston ash.

Ashfree dissolved solids behaved oppositely to inorganic solutes by being more skewed and more peaked in lines A, B. Since dissolved material contains leachates from living cells, from newly dead cells, and from older biogenic detritus, it has components from the second, third, and fourth steps beyond basic productivity. It is not surprising that it no longer follows either the skewness or kurtosis behavior of the inorganic solutes. Menzel (1964) found no correlation between primary production and dissolved organic matter. Dissolved organic matter is considered to be dominantly of refractory materials not readily decomposable (Menzel and Goering 1966). The greater skewness, greater peakedness, and greater range in lines A, B probably reflect local additions of dissolved materials on top of a "background" load.

Total phosphorus is measured on whole water. It is a combination of dissolved inorganic phosphorus plus the phosphorus contents of living cells, of detritus, and of dissolved organics in the water sample. The living cells and detritus are essentially the seston which has the skewness behavior of inorganic solutes. The inorganic distributional behavior of ortho-phosphorus plus the inorganic-like skewness behavior of seston, plus a possible greater lability of phosphorus than nitrogen may be a sufficient combination of reasons for the finding that total phosphorus behaves like an inorganic solute.

Total dissolved solids are measured on filtered water, the residue after evaporation is composed of originally dissolved inorganic and organic materials. Though the ash of dissolved solids is greater than its ashfree portion, the ashing has recovered inorganics that were bound into the organic molecules. Since the distributional behavior of total dissolved solids is similar to that of ashfree dissolved solids, the majority of the inorganics found as ash must have been bound in the organic molecules.

The Kjeldahl analysis is done on whole water. It measures nitrogen in the negative-three valence state. This includes ammonia, but the bulk of the material measured is the organic nitrogenous fractions of particulate matter in the water plus the nitrogenous fractions of dissolved organic matter. The finding that Kjeldahl nitrogen has the same behavior as ashfree total dissolved solids is consistent with the belief that much of the dissolved matter is dissolved organic matter. The quite different behavior of total phosphorus suggests that phosphorus may be only a minor constituent of the dissolved organic matter.

Conductivity is measured in whole water, hence in a mixture of particulate and dissolved organics plus dissolved inorganics. Though the organic fractions are probably in excess of the inorganics, the organics are overwhelmingly electrically neutral (nonconductors) and conductivity is essentially determined by the inorganic solutes. It is reasonable, then, that the distributional behavior of conductivity should be similar to that of the inorganics.

From the above it is believed that the skewness and kurtosis behaviors of the data from lines A, B and D, E show reasonable differences that are realistically relatable to the aquatic ecology of Lake Michigan.

No useful relations between the several other components of the frequency curves have been detected.

## CONCLUSIONS

The frequency curve technique of analyzing for differences in internal distribution of analysis values has revealed hitherto undetected differences between the stations of lines A and B and lines D and E. That this technique has shown differences between these pairs of sampling-station lines when other techniques or treatments have not is taken to indicate a superior sensitivity of the technique.

The differences revealed between lines A, B and D, E appear to be related in reasonable ways to significant facets of Lake Michigan's aquatic ecology.

Since sampling-lines A and B are located in the heavily populated and industrialized southern end of the lake and close to the demonstrably eutrophied extreme south end of the lake, it is probable and logical that they are more eutrophied than are lines D and E. It is concluded that the skewness and kurtosis behaviors of lines A, B are behaviors of beginning eutrophication not clearly detectable by other means. Whether the behaviors of lines D and E represent oligotrophy or only less advanced eutrophication is not known.

The frequency curve technique appears to offer real potential as a means of monitoring for small changes in eutrophic condition. Additional tests of the method will be required.

## REFERENCES

MENZEL, D. W. 1964. The distribution of dissolved organic carbon in the western Indian Ocean. Deep-Sea Res., 11: 757-765.

__________, and J. J. GOERING. 1966. The distribution of organic detritus in the ocean. Limnol. and Oceanogr., 11(3): 333-337.

POWERS, C. F. and A. ROBERTSON. 1965. Some quantitative aspects of the macrobenthos of Lake Michigan. Proc. 8th Conf. on Great Lakes Res.; Univ. of Mich., Great Lakes Res. Div. Pub. 13: 153-159.

RISLEY, C. and F. D. FULLER. 1965. Chemical characteristics of Lake Michigan. Proc. 8th Conf. on Great Lakes Res.; Univ. of Mich., Great Lakes Res. Div. Pub. 13: 168-174.

ROBERTSON, A. and C. F. POWERS. 1965. Particulate organic matter in Lake Michigan. Proc. 8th Conf. on Great Lakes Res.; Univ. of Mich., Great Lakes Res. Div. Pub. 13: 175-181.

SCARCE, L. E. 1965. The distribution of bacterial densities in Lake Michigan. Proc. 8th Conf. on Great Lakes Res.; Univ. of Mich., Great Lakes Res. Div. Pub. 13: 182-196.

U. S. PUBLIC HEALTH SERVICE. 1965. Report on pollution of the waters of the Grand Calumet River, Little Calumet River, Calumet River, Lake Michigan, Wolf Lake and their tributaries. U. S. Dept. Health, Education, and Welfare, Public Health Service, Div. of Water Supply and Pollution Control, Region V, Chicago, Ill., 46 p., 24 tables, 26 figs.

# ESTIMATED MONETARY VALUE OF MUNICIPAL-SUPPLY WATER FROM THE GREAT LAKES

John C. Ayers

In our dollar-standard culture it is customary and convenient to place monetary values on things. The author, probably along with others, has frequently felt the need for a monetary value, however crude, for the municipal-water-supply resource of the Great Lakes. To have such a figure would be to have a basis from which to make comparative judgments among the several water-use demands involved in the multiple-use concept.

Though the present estimate is crude, it is believed to have first-approximation value and to be a model from which a refined study could produce a reliable value for the municipal-supply use of Great Lakes water.

The basic figure used here was kindly provided by Mr. William Snell, Business Manager of the Milwaukee, Wis., Water Works. The use of a basic figure from Milwaukee is believed to have some degree of representativeness insofar, at least, as some cities must provide more water treatment than Milwaukee, while others provide less.

Since municipal water-supply may be in part tax-subsidized, tax monies for operation and capital expenditures (properly proportioned over time) should be added to water sales revenue to obtain the break-even (no profit) value unwittingly being placed upon municipal supply by the populace supporting each water-treatment facility. In a refined study actual figures for these items (plus any valid others) could be obtained.

To avoid any appearance to prying, and to obtain a population-related "mean annual water-bill" I asked Mr. Snell to solve for me the equation:

$$\frac{\text{Total Water-Sales Revenue + Tax Subsidy}}{\text{Number of Persons Served}} = \text{Mean per Capita Water Bill}$$

for a recent year. Mr. Snell computed, with Milwaukee's 1966 figures, a mean per capita annual "water bill" of $14.50 inclusive of industrial water usage.

Gamet (p. 243 in "Great Lakes Basin," Publication No. 71, American Association for the Advancement of Science, Washington, D.C., 1962) estimated from American data of 1958 and Ontario data of 1956 that a total of 15,982,841 Americans and Canadians were being provided municipal water from the Great Lakes. This figure so narrowly misses 16 million that the latter is accepted as a proper, even conservative, estimate of the populace being served.

If the Great Lakes populace-served of 16 million is multiplied by Milwaukee's mean annual per capita "water bill" of $14.50, the product is $232 million per annum.

The mean annual per capita water-bill as computed above is artificial in that revenue from water sold for industrial use is included in it. Consequently it is not readily subject to checking. Reasoning subjectively from what is known of raw-water quality at good-water sites like Charlevoix, Mich., and poor-water sites like Wyandotte, Mich., it appears that the spread of values for this "water-bill" might range from twice Milwaukee's figure ($29.00) to half of Milwaukee's figure ($7.25) or less. At half Milwaukee's figure the total of revenue and subsidy for the Great Lakes municipal supply would be $116 million.

In the first approximation it appears that the municipal-supply resource of the Great Lakes has a monetary value of the order of $100 million per year.

# PAPERS ALREADY PUBLISHED
# NOT REPRODUCED IN THIS REPORT

## BIOLOGY-CHEMISTRY

Particulate organic matter in Lake Michigan. A. Robertson and C. F. Powers. Proc. 8th Conf. on Great Lakes Res.; Univ. of Michigan, Great Lakes Res. Div. Pub. No. 13(1965): 175-181.

Some quantitative aspects of the macrobenthos of Lake Michigan. C. F. Powers and A. Robertson. Proc. 8th Conf. on Great Lakes Res.; Univ. of Michigan, Great Lakes Res. Div. Pub. No. 13(1965): 153-159.

The distribution of calanoid copepods in the Great Lakes. Andrew Robertson. Proc. 9th Conf. on Great Lakes Res.; Univ. of Michigan, Great Lakes Res. Div. Pub. No. 15(1966): 129-139.

A comparative study of Lake Michigan macrobenthos. Andrew Robertson and Wayne P. Alley. Limnology and Oceanography, 11(1966): 576-583.

The distribution of organic nitrogen in Lake Michigan. Andrew Robertson and Charles F. Powers. Papers Michigan Acad. Sci., 1967.

## GEOLOGY

A correlation of the currents and sedimentary activity in the Manitou Passage area of Lake Michigan. Wm. E. French. Ph.D. thesis, Univ. of Michigan, 1965. 48 p.

A correlation of the currents and sedimentary activity in the Manitou Passage area of Lake Michigan. Wm. E. French. Proc. 7th Conf. on Great Lakes Res.; Univ. of Michigan, Great Lakes Res. Div. Pub. No. 11(1964): 142-146.

Diving techniques as applied to geological investigations in the Great Lakes. Lee H. Somers. Proc. 10th Conference on Great Lakes Research, 1967.

## METEOROLOGY

The modification of warm air moving over cold water. F. R. Bellaire. Proc. 8th Conf. on Great Lakes Res.; Univ. of Michigan, Great Lakes Res. Div. Pub. No. 13(1965): 249-256.

The effect of air stability on wind and waves. A. E. Strong and F. R. Bellaire. Proc. 8th Conf. on Great Lakes Res.; Univ. of Michigan, Great Lakes Res. Div. Pub. No. 13(1965): 283-289.

The climatology of Lake Michigan. J. C. Ayers. Univ. of Michigan, Great Lakes Res. Div. Pub. No. 12(1965). 73 p.

The over-water development of a lake breeze in an offshore gradient flow. Alan E. Strong. Proc. 10th Conference on Great Lakes Research, 1967.

## PHYSICAL

On the decay of wind driven currents. V. E. Noble. Ocean Science and Ocean Engineering; Trans. Marine Tech. Soc.-Amer. Soc. Limnol. Oceanog. Conf., 1965, p. 544-554.

Observations of the fall overturn of Lake Michigan. V. E. Noble. Limnology and Oceanography, 11(1966): 413-415.

Current patterns and lake slope. Frank R. Bellaire and John C. Ayers. Proc. 10th Conference on Great Lakes Research, 1967.